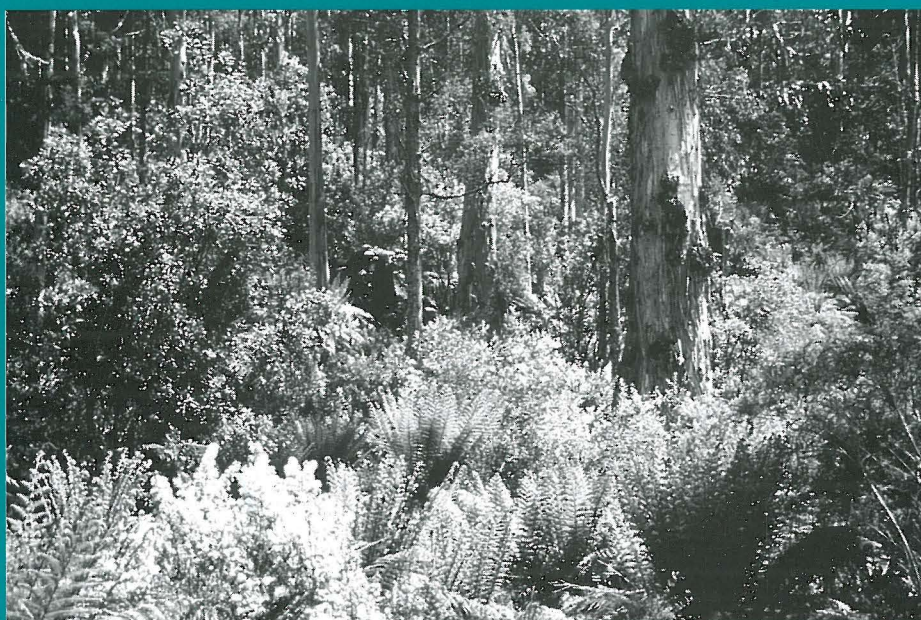


Vegetation classification and mapping systems for Australian forest management



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Vegetation classification and mapping systems for Australian forest management

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Summary

This working paper provides a detailed review of the major vegetation classification and mapping systems used by the major forested land management agencies in Australia, with a focus on the clarification of vegetation units, methods used and principal outcomes of classification and mapping. It also provides a comparison of the different nomenclatures against a simplified standard to allow some understanding of how the different systems relate to each other. This paper is written for all people who are involved in vegetation management and ecological studies, in particular those who are involved in the Comprehensive Regional Assessment process. It is a comprehensive reference manual to the major vegetation classification systems used currently in Australia.

The recognition of forest types is important for land management agencies as it provides a basis for the development of forest management policy and forest management strategies. Different systems for classifying and describing forest vegetation have been developed by various forested land management agencies in Australia to suit their own needs. There has been a lack of common understanding about the vegetation classification systems being used in different States, or between different agencies within single States.

Of all the systems reviewed, Specht (1970) and Walker and Hopkins (1990) are the most used in Australia. The Specht (1970) system is a two-way structural classification scheme based on the life form, height, and projective foliage cover of the tallest stratum. Modifications of this system have been carried out by some agencies, largely by the addition of floristic subunits and changes in height classes to suit local ecological conditions. The Walker and Hopkins (1990) system is partially based on Specht's approach and uses the growth form, height and crown cover of the vegetation, complemented by the dominant or diagnostic species.

Some relatively new classification systems, such as ecological vegetation classes, multi-attribute classification, and regional ecosystems, have been developed to suit various specific study and management objectives. These systems have shown some potential for wider application in Australia.

Most vegetation classification systems reviewed are similar in using both floristics and structure as two primary elements in classifying vegetation types, and all use growth form (physiognomy) for distinguishing vegetation units. The classification and mapping systems for wood production purposes differ from those for conservation and environment purposes in several aspects - wood production classifications emphasize commercial tree species and/or attributes such as height, whereas conservation classifications emphasize ecology, vegetation coverage, and the importance of understorey species.

The review found three broad strategic approaches in the vegetation classification programs being undertaken by the major forest land management agencies in Australia:

- conducting a single classification across the whole of the agency's land in a State (e.g. Forestry Commission of New South Wales, Parks and Wildlife Commission of the Northern Territory)

- conducting vegetation classification at regional level, but using the same methods in each region (e.g. Queensland Herbarium, Royal Botanic Gardens Sydney)
- using different methods depending on the specific objectives of individual studies (e.g. NSW National Parks and Wildlife Service).

This paper highlights the value of accurate quantitative measurements in the field. For example, for the two key structural attributes of height and crown density, the measured raw data can be accommodated by a number of different classification schemes.

1. Introduction

Early descriptions of plant cover on the land focused on the distribution of major life form (trees, shrubs) and individual dominant species (e.g. spotted gum *Eucalyptus maculata*). In Australia, the advance in understanding of the taxonomy of the Australian flora through the work of Brown (1810), Mueller (1858-82) and Bentham (1863-78) encouraged this floristic approach. In Europe and North America, this floristic emphasis underwent a rapid change to largely ecological studies in the early twentieth century following the pioneering works of Schimper (1903), Cowles (1899, 1901), Clements (1904, 1905, 1907) and Warming (1909). There was a growing awareness that distinct plant groupings or communities (Grisebach 1872) could be recognised, not only by floristic composition, but also by their distinctive life forms, their habitat and their structure. The climax plant community concept of Clements (1916), that it was primarily the climate that determined a monoclimate vegetation for an area, dominated ecological thought at that time.

Comprehensive reviews of vegetation classification schemes that have been applied throughout the world have been provided by Whittaker (1962) and Fosberg and Pearsall (1993). Seven criteria were listed by Whittaker (1962) in the classification of plant communities:

- (1) physiognomy—the general external appearance of plants; gross life form (tree, shrub, fern, herb, moss, lichen) and special life form (epiphyte, liane, succulent, etc.)
- (2) structure—the vertical and horizontal spatial distribution of plants
- (3) floristic composition
- (4) habitat or environmental relations
- (5) function—the adaptational characteristics of plant phenotypes
- (6) dynamics—the successional characteristics
- (7) history.

In Australia, vegetation classifications have primarily used the first four criteria. For most areas in Australia, the number of vegetation ecologists is small, the survey areas extensive, and the level of taxonomic knowledge of the plant species is limited. These conditions promoted the use of structural classifications. Exceptions to this were found in Victoria which is a relatively small, well populated State. Here, detailed floristic-based vegetation studies were extensively used (e.g. Gullan *et al.* 1981).

The recognition of forest types is important for land management agencies as it provides a basis for development of forest management policy and forest management strategies. Although there have been several attempts to construct a nationwide vegetation classification (Moore and Perry 1970, Specht *et al.* 1974, Beadle 1981, AUSLIG 1990, RAC 1992), different systems for classifying and describing forest vegetation have been developed by various forested land management agencies in Australia to suit their own situations. The lack of common understanding across the country about the vegetation classifications systems being used in different States, or between different agencies within single States, became particularly evident in the early stages of the Comprehensive Regional Assessment of forests (the Deferred/Interim Forest Assessment process).

With the growing knowledge of the flora of Australia, the emphasis in vegetation description followed the overseas trend and moved to ecological studies in the 1930s. The 1:10 million (m) map of the vegetation of Australia (Prescott 1931), although very generalised, demonstrated the usefulness of a structural vegetation map. Within ten years, several important plant communities were described ecologically (e.g. Patton 1933, 1934, 1936, Wood 1936, 1937, Blake 1938).

Relief, drainage and soil differences, particularly mineral deficiencies, as well as climatic history and variable physiological tolerances of plants were used to explain departures from the expected Clementian climax vegetation (Crocker 1959, Crocker and Wood 1947, Specht 1957, 1963, Cochrane 1967).

Since the 1930s overseas and the 1950s in Australia, there has been a growing awareness of the value of vegetation studies based on physiognomy (Du Rietz 1930, 1931, Richards *et al.* 1940, Kùchler 1947, 1949, 1956, 1967). Important structural classifications were devised by Kùchler (1947), Wood (1949), Dansereau (1951) and Christian and Perry (1953). Physiognomic vegetation maps of Australia based on the classification of Dansereau (1951) were produced by Williams (1955) and Wood and Williams (1960). Other maps of Australian vegetation by Cochrane (1963, 1967) were based on Kùchler's physiognomic classification and allowed comparative studies with published world maps.

A review of vegetation classification and mapping systems in use in Australia was conducted by Kestel Research (1990) for the National Forestry Inventory of the Bureau of Resource Sciences (BRS). The review provided useful information by covering all States/Territories, but it lacked depth and scope in its assessment, as it largely depended on personal conversations and individual presentations in workshops. As a result, it lacked references to original works, which limited the understanding of how the vegetation was classified and mapped.

The objectives of the present review are to compare vegetation classification and mapping work undertaken by the major forest management agencies in Australia, and to provide a brief summary of the systems and methods adopted in the work. This review draws mainly from the published literature. It covers most major vegetation classifications produced and aims to provide more detailed information on each classification, with a focus on the clarification of vegetation units, methods used and principal outcome of the work. We include in this report a comparison of the different nomenclatures against a simplified standard to allow some understanding of how the different systems relate to each other (see Table 1, Fig. 1). The review does not aim to provide an intensive evaluation of the methods used, and does not attempt to produce a uniform classification system for Australian forest vegetation types.

Table 1. Main components of vegetation classification and mapping systems used by major forest management agencies in Australia

Floristics		Growth form	Structure		Height for the highest class (m)	Levels of hierarchy in classification	Mapping scale	Basic classification unit	
Dominance	Character species relation		Height	Crown density				As named by users	"Standardised" for comparison ⁵ based on Beadle & Costin (1952)*
OS	US			PFC CC (no. of classes)					
For wood production purposes									
NSW SF	+	+	+	(6)	+	3	1:25 000	Forest type	Association (p.p.)
QLD DPI Forestry	+	+	+	(6)	>40	2	1:25 000	Forest type	Association
Vic DNRE									
former forest types	+	+	+	(4)	>40	2	1:63 360	Forest type	Association
new forest mapping	+	+	+	(6)	>51	2	1:25 000	Forest type	Association
SA DPI Forestry	+	+	+	(3)	>30	2	1:2 000 000	Forest type	Association
TAS Forestry		+	+	(7)	>76	3	1:25 000	Forest type	Formation
For conservation & environmental purposes									
NSW NPWS									
Coastal veg. mapping	+	+	+	(9)	>35	3	1:25 000	Plant association	Association
Multi-attribute mapping	+	+	+	+		1		Plant association	Association
Rainforest	+	+	+	(3)		3		Suballiance	Suballiance
Wheatbelt region		+	+	(9)	>30	2	1:250 000	Map unit	Association
NSW RBG	+	+	+	(3)	>30	2	1:100 000	Plant community	Association
NSW DLWC		+	+	+					Formation
QLD Herbarium	+	+	+	(3)	>30	2	1:250 000	Vegetation group	Association
QLD DEH	+	+	+	(9)	>35	1		Regional ecosystem	Alliance
Vic DNRE									
Floristic communities	+	+	+			2	1:250 000	Subcommunity	Association
Eco. veg. classes		+	+			1	1:1 000 000	Eco. veg. classes	Formation
Vic LCC	+	+	+	(4)	>40	2	1:1 000 000	Vegetation unit	Association
SA DENR	+	+	+	(3)	>30	2	1:1 000 000	Plant community	Association
SA DHUD		+	+			2		Plant community	Association
WA CALM	+	+	+	(5)		2	1:25 000	Forest type	Association (pp)
WA Dept. Ag	+	+	+			2	1:250 000	Site type	Alliance
TAS NPWS			+			2		Plant communities	Association
NT PWCNT	+	+	+	(3)	10-30	2	1:1 000 000	Plant community	Association
ACT ACTFS	+	+	+	(3)	>30	2	1:25 000	Plant association	Association

OS=overstorey; US=understorey; PFC=projective foliage cover ratings; CC=crown cover; pp=in part. * (in descending order) Formation, alliance, suballiance, association.

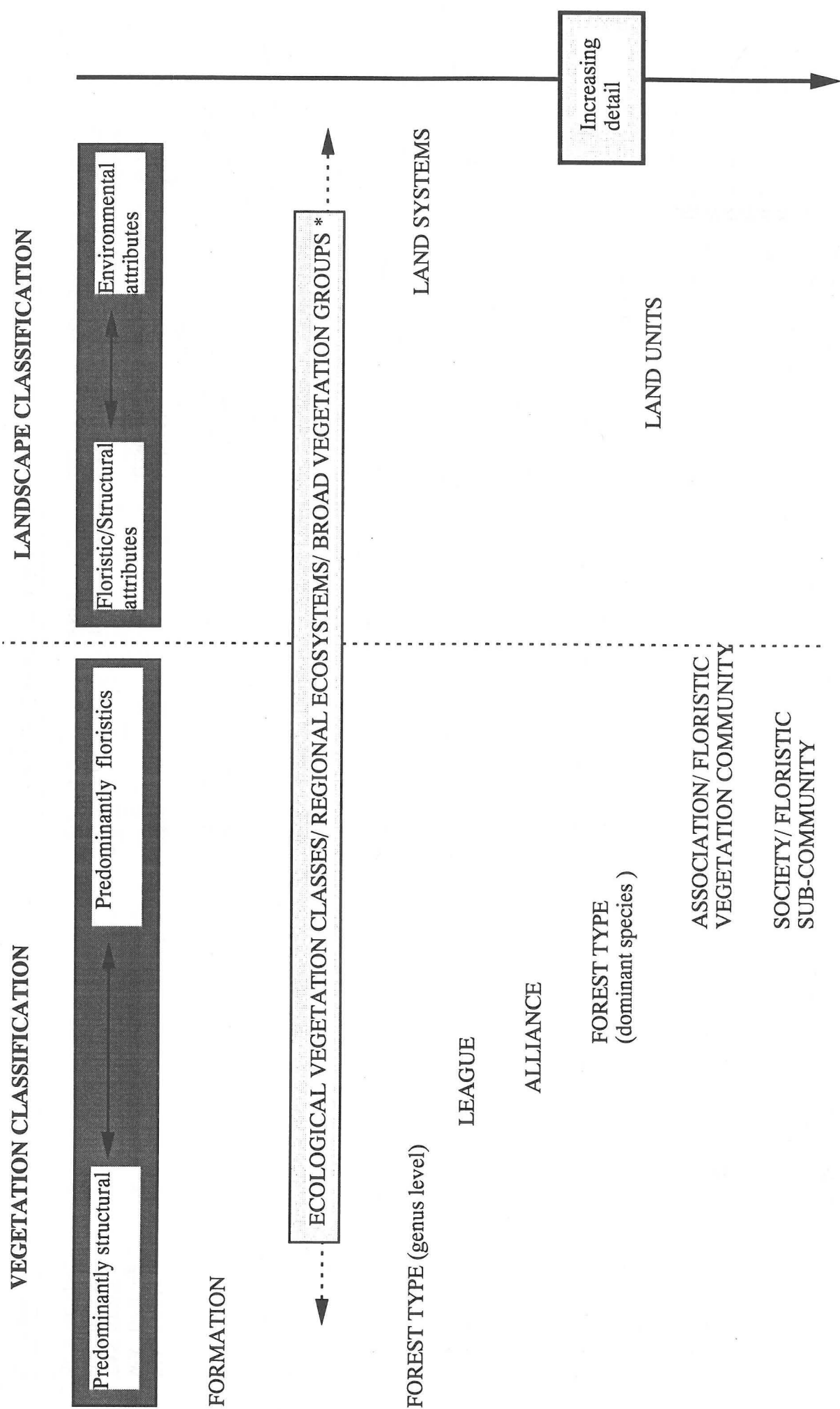


Fig. 1. Relationship of major vegetation classification units used in Australia

* The definition of these higher level groupings can use a variety of structural, floristic and environmental attributes. The degree of heterogeneity within these units may vary.

2. Major vegetation classification and mapping systems used in Australia

This section summarises the systems most used by forest, land, conservation and environment management agencies in Australia, and aims to provide a self-explanatory description for each major system. The review provides a comprehensive reference manual to the major vegetation classification systems used currently in Australia.

2.1 Specht

As part of the International Biosphere Project, Specht (1970) devised a two-way structural classification scheme for vegetation, based on the life form, height, and projective foliage cover of the tallest stratum (Table 2). Projective foliage cover (PFC) was defined as the proportion of land covered by one or more layers of photosynthetic tissue above it (Specht 1970). This scheme avoided the use of ambiguous terms such as "wet" and "dry" that were widely used in Australian vegetation description until that time. Specht (1981) claimed that PFC of the tallest stratum provides a ready assessment of the photosynthetic potential of the plant community, and that the above-ground biomass is an important measure of how environmental factors may affect growth. In this system, plant communities which have essentially the same structural characteristics are grouped under one structural formation based on height and PFC of the tallest stratum, although they may differ in floristic composition in all strata.

Table 2. Nomenclature of structural formations (Specht *et al.* 1974)

Form and height class of tallest stratum ¹	Projective foliage cover of tallest stratum			
	Dense (70-100%)	Mid dense (30-70%)	Sparse (10-30%)	Very sparse (<10%)
Trees >30 m	Tall closed forest	Tall open forest	Tall woodland	Tall open woodland
Trees 10-30 m	Closed forest	Open forest	Woodland	Open woodland
Trees 5-10 m	Low closed forest	Low open forest	Low woodland	Low open woodland
Shrubs 2-8 m	Closed scrub	Open scrub	Tall shrubland	Tall open shrubland
Shrubs 0-2 m	Closed heath	Open heath	Low shrubland	Low open shrubland
Shrubs < 1 m			Dwarf shrubland	Dwarf open shrubland
Hummock grasses	—	—	Hummock grassland	Open hummock grassland
Herbs	Closed herbland	Herbland	Open herbland	Ephemeral herbland
	(1) Closed tussock grassland	(1) Tussock grassland	(1) Open tussock grassland	
	(2) Closed grassland	(2) Grassland	(2) Open grassland	
	(3) Closed herbfield	(3) Herbfield	(3) Open herbfield	
	(4) Closed sedgeland	(4) Sedgeland	(4) Open sedgeland	
	(5) Closed fernland	(5) Fernland	(5) Open fernland	
	(6) Closed mossland	(6) Mossland	(6) Open mossland	

¹ A tree is defined as a woody plant > 5 m tall, usually with a single stem. A shrub is a woody plant < 8 m tall, frequently with many stems arising at or near the base.

Although this system lacks a floristic component, it is probably the most used system in Australia, and is applied to some extent in all States/Territories. Modifications have largely been carried out by the addition of floristic subunits and changes in height classes to suit local ecological conditions. However, PFC has been found to be unsatisfactory where there are either deciduous species or species with vertical or near-vertical leaves, and to be difficult to estimate where lower vegetation blocks the line of sight to upper strata (Walker and Hopkins 1990). In practice, PFC is rarely *measured* in the field (i.e. using cross-wire sighting tubes as recommended by Specht 1981), but *estimated* by eyeballing. More systematic line intercept techniques (e.g. Neldner and Clarkson 1995) have been used to provide PFC measures that are comparable between sites.

2.2 Walker and Hopkins

This system is partially based on Specht's approach and uses the growth form, height and crown cover of the vegetation, complemented by the dominant or diagnostic species (Walker and Hopkins 1990). Rainforest is considered separately from non-rainforest vegetation. The structural formation classes are defined by height (Table 3), growth form and crown cover (Table 4).

Crown cover – the percentage of the sample site within the vertical projection of the periphery of crowns – is estimated using the mean gap between crowns divided by mean crown width (crown separation ratio). In this case, crowns are treated as opaque. Estimation of crown cover is considered to be less time-consuming in the field than PFC. The arbitrary crown classes of Walker and Hopkins (1990) (Table 4) have been selected to coincide as closely as possible with the projective foliage cover classes of Specht. Walker and Hopkins (1990) on the basis of the Carnahan's definition of percentage plant cover (Carnahan 1976), introduced the concept of foliage cover (the percentage of the site occupied by the vertical projection of foliage and branches), and provided a formula to convert crown cover to foliage cover:

Foliage cover = crown cover x crown type (degree of openness)

Reference photographs showing crown types ranging from 40 to 70% for various leaf sizes are provided by Walker and Hopkins (1990).

In the Walker and Hopkins system, both dominant and co-dominant species and indicator species are used for naming non-rainforest floristic associations. Dominant species are the most abundant or physically predominant species in the tallest stratum, while the co-dominant species are other upper stratum species which are always present and conspicuous. An indicator species is a species of known environmental preferences or of such abundance that it cannot be ignored, and is selected from any stratum, usually a lower stratum. For rainforest classification, leaf size is used as a key feature and its categories are described in Webb (1978).

Table 3. Height classes for woody plants (Walker and Hopkins 1990)

Class	Height (m)	Trees, vines, palms	Shrubs, heath shrubs chenopod shrubs, mallee (tree or shrub form), cycads
9	>35.01	Extremely tall	NA
8	20.01-35	Very tall	NA
7	12.01-20	Tall	NA
6	6.01-12	Mid-high	Extremely tall
5	3.01-6	Low	Very tall
4	1.01-3	Dwarf	Tall
3	0.51-1	NA	Mid-high
2	0.26-0.5	NA	Low
1	<0.5	NA	Dwarf

NA not applicable.

The Walker and Hopkins classification is used unmodified by some research organisations (especially CSIRO), but is more generally modified to increase rapidity of sampling by less well-trained field workers. It is currently used in Queensland (e.g. by Department of Environment since 1984 and by Department of Primary Industries Forestry). In New South Wales it is used by the National Parks and Wildlife Service and Royal Botanic Gardens Sydney, in combination with floristic analyses and aerial photo interpretation (API), to classify vegetation.

Table 4. Structural formations by growth form and crown separation for woody plants (Walker and Hopkins 1990)

Crown separation	Closed or dense	Mid-dense	Sparse	Very sparse	Isolated plants	Isolated clumps
Field criteria	Touching-overlap	Touching-slightly separated	Clearly separated	Well separated	Isolated	Isolated
Crown separation ration	<0	0-0.25	0.25-1	1-20	>20	>20
Tree	Closed forest	Open forest	Woodland	Open woodland	Isolated tree	Isolated clump of trees
Tree mallee	Closed mallee forest	Open mallee forest	Mallee woodland	Open mallee woodland	Isolated mallee trees	Isolated clump of mallee trees
Shrub	Closed shrubland	Shrubland	Open shrubland	Sparse shrubland	Isolated shrubs	Isolated clump of shrubs
Mallee shrub	Closed mallee shrubland	Mallee shrubland	Open mallee shrubland	Sparse mallee shrubland	Isolated mallee shrubs	Isolated clump of mallee shrubs
Heath shrub	Closed heathland	Heathland	Open heath	Sparse heath	Isolated heath shrubs	Isolated clump of heath shrubs
Chenopod shrub	Closed chenopod shrubland	Chenopod shrubland	Open chenopod shrubland	Sparse chenopod shrubland	Isolated chenopod shrubland	Isolated clump of chenopod shrubland

2.3 Johnston and Lacey

Johnston and Lacey (1984) put forward a proposal for a classification system of tree-dominated vegetation in Australia. They proposed that a classification system should be based upon intrinsic attributes of the vegetation, rather than upon its environment; be capable of being used at a range of scales of resolution; and be comprehensive in terms of the variety of woody vegetation associations that can be incorporated. Their fairly complex system is based primarily upon physiognomic, floristic and spatial characteristics. It has not been adopted for use in vegetation mapping of forests by land management authorities in Australia, although it contains some important conceptual approaches to the ways of vegetation classification in Australia.

2.4 Forest 'type' mapping

Baur's system (FCNSW 1989) is a typical example of a forest typing classification. It is basically a floristically orientated vegetation classification system biased towards commercially valuable tree species and with limited quantitative information on forest structure, particularly crown density. Compared with those of Specht and Walker and Hopkins, this system uses a more traditional and descriptive approach in classifying forest types. Although the classification of forest type is made subjectively and is not based on detailed studies of species relations, it is widely used in forest management planning and policy determination at both regional and State levels, particularly in NSW, because each type is readily recognised in the field. It formed the basis of Beadle's classification of the tall eucalyptus forests of the eastern coastal lowlands of NSW (Beadle 1981). In Tasmania, the forest typing system uses the structural attributes of tree height and crown cover to classify forests, with very limited floristic information given.

2.5 Beadle

This vegetation classification system was initially described in Beadle and Costin (1952) and slightly modified in Beadle (1981). The scheme proposed by Beadle and Costin (1952) was the first attempt to provide uniformity in classificatory units and terminology for Australian vegetation. It was "based on the principle that vegetation should be described objectively in terms of its floristics and structure without reference to the complex of factors governing it (the interpretation of the status of the community is not part of this descriptive account)" (Beadle and Costin 1952, pp. 61-62). Their classification scheme was modified from European and American systems, and allowed workers to describe the present vegetation, without having to be preoccupied with its successional status. It allowed a flexibility in emphasis from essentially floristic to essentially structural, although the combined floristic-structural classification was considered most valuable for Australian studies.

Table 5. Structural forms and subformations (Beadle 1981)

Structural form	Main subforms	Usual height of woody component 70-100% = closed <30% = very open	Projected foliage cover (based on Specht) 30-70% = open
Rainforest	Mesophyll vine forest	16-42 m	closed
	Notophyll vine forest	21-45 m	closed
	Microphyll vine forest	6-20 m	closed
	Nanophyll moss forest	18-42 m	closed
Forest (trees with long boles)	Tall forest	25-80 m	closed to open
	Low forest	15-25 m	open
Woodland (trees with short boles)	Tall woodland	10-15 m	open
	Low woodland	5-10 m	open to very open
	Shrub woodland	5-10 m	open to very open
	Savannah woodland	5-10 m	open to very open
Mallee		3-8 m	closed to very open
Shrubland	Tall shrubland	3-6 m	closed to open
	Low shrubland	2-3 m	closed to very open
	Heath	1-2 m	closed to very open
	Halophytic shrubland	60-100 cm	open to very open
Savannah	Tree savannah		closed to very open
	Shrub savannah		closed to very open
Grassland	Hummock grassland		open to very open
	Tussock grassland		closed to very open
	Sod grassland		closed
Sedgeland		closed	
Mossland			closed
Forbland	Perennial forbland		closed
	Annual forbland	varying	

Beadle's system classifies vegetation on the basis of life form, leaf size, and floristics according to the dominants, giving due consideration to structure (Table 5). Plant communities are classified into associations, the basic floristic classification unit, which are then grouped into alliances. An association is defined as a climax community of which the dominant stratum has a qualitatively uniform floristic composition, and exhibits a uniform structure as a whole. An alliance is defined as a group of floristically-related associations of similar structure. The definition of association has been used in NSW (National Parks and Wildlife Service) and Queensland (Queensland Herbarium).

2.6 Webb (rainforest)

Both the structural (height and leaf size) and physiognomic features (the presence of vines, palms, ferns, epiphytes and buttressing) form important elements for the classification of Australian rainforests (Webb 1959, 1968, 1978). Forests are classified as tall if greater than 37 m, medium 18-37 m and low 9-18 m. Leaf sizes are considered to be an important structural feature in classifying rainforests and are divided into five classes (Table 6). The system is often used in conjunction with Specht, and components of it are incorporated as attributes in the rainforest

classification of Walker and Hopkins (1990). It is considered to be particularly well-suited to the subtropical and tropical rainforests of Queensland. However some concerns have been raised over the difficulty of determining the leaf size in the canopy, and over the fact that this system has only a small floristic component.

Table 6. Leaf size categories (Webb 1978)

Leaf size category	Leaf size	Leaf length (cm)
Macrophyll	The largest leaves	>25.0
Mesophyll	Large leaves	12.5-25.0
Notophyll	*	7.5-12.5
Microphyll	Little larger leaves	2.5-7.5
Nanophyll	Smallest leaves	<2.5

* No name was given in Webb (1978).

2.7 Floyd (rainforest)

This is a structural-physiognomic-floristic classification system developed from Webb (1968) and Beadle (1981) for rainforest. Floyd (1990) stated that the system is the most precise classification for NSW rainforests, because it acknowledges the importance of climate and environment in the distribution of rainforest type and species. This system is also used for rainforest description in the cooler and drier rainforests of Victoria. Floyd (1990) considers that it is possible to establish a compatibility table with Webb's classification.

2.8 Jarman, Brown and Kantvilas (rainforest)

The cool temperate rainforests of Tasmania have been classified into four major types based on structure and species composition by Jarman *et al.* (1984). The general characteristics of the types are summarised in Table 7. There are a number of different communities in each type, and they have been described in Jarman *et al.* (1987).

Table 7. Major Tasmanian rainforest groups (from Jarman *et al.* 1987)

Rainforest group	Characteristics	Typical species
Callidendrous (3 communities)	Trees tall, well-formed (lowland)	Dominant trees: <i>Nothofagus cunninghamii</i> , <i>Atherosperma</i>
	Understorey park like Angiosperm diversity low	Shrubs: <i>Pittosporum</i> , <i>Aristotelia</i> , <i>Coprosoma quadrifida</i> , <i>Telopea truncata</i> , <i>Tasmannia</i>
	Fern diversity high	Ferns: <i>Dicksonia</i> , <i>Polystichum</i> , Epiphytic species
Thamnic (6 communities)	Trees of moderate height	Dominant trees: <i>Nothofagus cunninghamii</i> , <i>Eucryphia</i> <i>lucida</i> , <i>Lagarostrobos</i> , <i>Athrotaxis</i> <i>selaginoides</i> , <i>Phyllocladus</i>
	Understorey shrubby but relatively open Angiosperm diversity moderate	Shrubs: <i>Anodopetalum</i> , <i>Anopterus</i> , <i>Cenarrhenes</i> , <i>Richea pandanifolia</i> , <i>Trochocarpa</i> , <i>Archeria</i>
	Fern diversity moderate	Ferns: <i>Blechnum wattsii</i> , Epiphytic species
Implicate (5 communities)	Trees low, canopy open	Dominant trees: <i>Nothofagus</i> spp., <i>Lagarostrobos</i> , <i>Phyllocladus</i> , <i>Arthrotaxis selaginoides</i> , <i>Leptospermum</i> spp., <i>Eucryphia</i>
	Understorey tangled Angiosperm diversity high	Shrubs: Dominants above + <i>Richea</i> <i>pandanifolia</i> , <i>Anodopetalum</i> , <i>Agastachys</i>
	Fern diversity low	Ferns: sporadic <i>Blechnum wattsii</i>
Open montane (3 communities)	Trees low, canopy open	Dominant trees: <i>Athrotaxis cupressoides</i>
	Understorey dense, shrubs 1-8 m Angiosperm diversity moderate	Shrubs: <i>Nothofagus</i> spp., <i>Diselma</i> , <i>Microstrobos</i> , <i>Podocarpus</i> , <i>Orites</i> spp., <i>Richea</i> spp., <i>Baeckia gunniana</i> , <i>Leptospermum</i> <i>rupestre</i>
	Fern diversity low	Ferns: None consistent

2.9 Integrated surveys

The primary purpose of integrated surveys was to map and describe land systems. Maps of vegetation have been derived from this land system mapping. A land system has been defined by

Christian and Stewart (1953) as an area or group of areas where there is a recurring pattern of topography, soils and vegetation. Each land system may be made up of a number of individual components called land units. Frequently a land unit will be composed of predominantly one vegetation type, and for the purpose of vegetation mapping, the land unit is what is delimited on the resulting vegetation map as a vegetation mapping unit. Because of the constraints of scale, individual mapping units are often unable to be shown cartographically and have to be amalgamated into mosaics. This amalgamation is usually done on a land system basis. For example, the alluvial land systems in the Western Arid Region Land Use Study (WARLUS) studies frequently consist of a number of vegetation types (land units), which may include *Eucalyptus* spp. fringing woodlands, chenopod succulent shrublands, and grass or forb dominated open herblands. For the purpose of a land system study, these are all mapped as one land system. However, for the purpose of a vegetation map, it is important to try to separate these different vegetation communities as different units on the map, if this is permitted by the scale. The CSIRO Land Research Series, e.g. Austin (1978), and studies by State Primary Industry Departments have used a land system approach. The mapping of "vegetation complexes" of Heddlé *et al.* (1980) in Western Australia is essentially land system mapping. Keith and Saunders (1990) related the 41 plant communities of the Eden region, NSW, which were defined on the basis of floristic composition, structure and environmental variables, to the mapped land systems of Austin (1978) to provide a preliminary assessment of representativeness of the reserve network.

2.10 Other classification systems

Gillison and Walker (1981) produced a classification of Australian woodlands, using height and foliage cover boundaries but with different height boundaries (2, 3, 6, 12 and 20 metre cutoffs) from those of Specht (1970). Both tree and shrub life forms of the same species (e.g. *Acacia aneura*) could be included in this classification. Gillison (1981, 1984, 1988) proposed the functional attribute or modal approach for surveys designed to develop predictive functions. The modal attributes were leaf size, leaf angle, leaf type, and structural units of life form. This system allowed vegetation to be described using only physiognomic attributes, but did not classify the vegetation using a finite number of classes or "pigeon holes".

Some relatively new classification systems have been developed to suit various specific study and management objectives, notably ecological vegetation classes (Woodgate *et al.* 1994), multi-attribute classification (NPWS 1995) and regional ecosystems (Young 1995). These systems have showed some potential in application in Australia. For example, a regional ecosystems approach has been used in Western Australia (Brooker and Margules in press). The ecological vegetation classes system has been recommended as one of the important vegetation classification methods for the old-growth forest study project in southeastern Queensland (Irvine 1994). Details of these systems are described in Section 3.

2.11 Site attribute quadrats

The collection of primary site attribute data is widely undertaken by research organisations (especially CSIRO) and State and Territory agencies. Adequately sampled site data are essential for the description and modelling of individual species, and for the description of community patterns in the environment. They form the basis for most numerical and intuitive classifications of vegetation. A minimum sampling requirement of a listing of all species at a site, together with

a limited set of structural attributes, was suggested by Austin (1983) and Pedley (1988). More recent developments include the concept of core attributes for terrestrial biological survey data in Australia (Bolton 1992, Davey *et al.* 1993).

3. Vegetation classification in each State/Territory

3.1 New South Wales

3.1.1 State Forests of New South Wales

State Forests of New South Wales (SFNSW) uses forest types initially described by Baur (1962, 1968) and refined by FCNSW (1989). A forest type is defined as any group of tree-dominated stands which possess a general similarity in composition and character. Stands in a forest type may be expected to respond to silvicultural treatments in a similar manner to each other. As noted in FCNSW (1989), the classification was not intended as an ecological classification of forest vegetation but primarily as an aid to forest management. It was also designed to provide a basis for a practical achievable uniform forest mapping coverage for state forests. Forest types are mapped by API at a scale of 1:25 000. The smallest area delineated is 2 hectares in size or 50 m in width for narrow communities.

The classification of forest types of NSW is based on the occurrence of one or more indicator species in the canopy, which characteristically achieve a degree of predominance (normally at least 50% of the basal area of canopy trees) in the relevant stands. The structural information (height and canopy continuity) used in the classification is a qualitative description and is not based on the quantitatively defined classes like that of Specht (1970) or Walker and Hopkins (1990). In this classification, a tree is defined as an erect woody plant with a single stem at ground level, and height greater than 7.5 metres. The classification consists of three hierarchical levels: (1) group; (2) league and (3) forest type. There are a total of three groups (rainforest group, eucalyptus and related-group, and non-forest and artificial group), 25 leagues and 194 forest types.

The rainforest group includes four leagues (subtropical rainforest, warm temperate rainforest, cool temperate rainforest, and dry and depauperate rainforest) distinguished primarily on the structural complexity of the communities. The floristic composition tends to closely parallel the structural classification. For example, the subtropical rainforest league has a mixed floristic composition and diversity of life forms, whereas the warm temperate rainforest has only two layers and a simpler composition. The four leagues are further divided into 24 forest types mainly based on species composition. For example, the forest type Booyong refers to subtropical rainforest where White Booyong (*Argyrodendron trifoliolatum*) and Black Booyong (*A. actinophyllum*) are the most plentiful species, while the Yellow Carabeen type is similar but generally dominated by Yellow Carabeen (*Sloanea woollsi*).

The eucalyptus and related-group includes 17 leagues, recognised partly on the basis of structure and/or habitat, and partly on species composition. It consists of 148 forest types, which occupy over 90% of the State Forest area. The Blackbutt league is considered the most valuable and important timber-producing league. It contains 7 forest types in which Blackbutt is either clearly the dominant species, such as the Moist Blackbutt (*E. pilularis*) forest type, or co-dominant with other species, such as the Blackbutt-Spotted Gum (*E. maculata*) forest type.

3.1.2 National Parks and Wildlife Service of New South Wales

Intensive studies have been undertaken by NSW National Parks and Wildlife Service (NPWS) to produce detailed vegetation classifications and maps of national parks, nature reserves and vacant crown land. Unlike the SFNSW which uses a single vegetation classification and mapping system across the State, the NPWS has adopted different survey and classification methods depending upon the specific objectives of individual studies. Three major projects undertaken in NSW are described here.

Upper Northeast New South Wales

Two methods of vegetation mapping, namely coastal vegetation mapping and multi-attribute vegetation mapping, are used for coastal areas and non-coastal locations respectively to classify and map the previously unsurveyed national parks, nature reserves and selected vacant and other crown land of upper northeast New South Wales. The objective of the classifications is to provide accurate baseline information for the Regional Audit program designed by the New South Wales Natural Resources Audit Council (NPWS 1995).

The coastal vegetation mapping system classifies vegetation into a three-level hierarchical framework starting with formation, followed by subformation and association, the basic vegetation unit. Formations are named using the growth form and crown cover categories of Walker and Hopkins (1990). Subformations are derived from the ecological classification of Beadle and Costin (1952), while associations are named after the dominant species (floristics) in the dominant stratum identified during photo interpretation of 1:25 000 scale colour photographs and field survey (NPWS 1995). Vegetation height is not used in this classification system.

Multi-attribute vegetation mapping is also based on the delineation of mapping units on 1:25 000 colour aerial photographs. It uses a hierarchical classification based on the canopy attributes of height, using Specht (1970) categories; crown cover classes similar to Walker and Hopkins (1990); qualitative crown size categories (large, medium, small); and the floristic associations present. A coding system for each of these attributes is used for each polygon (NPWS 1995).

One advantage of this method is that it can produce a number of structural/floristic combinations of vegetation (NPWS 1995). Geographic information systems (GIS) can manipulate the vegetation information stored in coverage databases to generate maps according to specific attributes selected by the user. For example, they can generate maps of all closed forests or a particular floristic group. This coding system has been developed so that the "attributes should be mapped in as primary form as possible", but like the similar coding systems devised by Beard (1979a) and AUSLIG (1990) the structural attributes are put into predetermined classes.

State forests of upper northeast NSW have been mapped by SFNSW using the Baur's forest typing system, and these forest types form the majority of the mapping for the region. As a single consistent classificatory system is a more useful tool for a regional audit, NPWS (1995) attempted to integrate map units from forest typing, coastal vegetation mapping and multi-attribute mapping. This integration was attempted using two approaches, a computer-based numerical classification, and recoding map units by vegetation mapping experts, with both approaches involving amalgamation and recoding of polygons. Details of the integrated classification results are given in NPWS (1995), which discusses both limitations and merits of the two approaches.

As no attempt was made to join boundaries at the edge of areas mapped using different classifications, this study illustrates the difficulty in trying to integrate different approaches into a single classification. Similar difficulties were experienced by Pickhard and Boyland (1981) when they tried to integrate three small scale vegetation maps at the Queensland, New South Wales and South Australian borders.

NSW rainforest

Floyd (1990) divided New South Wales rainforests into four subformations (subtropical rainforest, dry rainforest, warm temperate rainforest and cool temperate rainforest), 13 alliances and 57 suballiances. As noted by Floyd (1990), his structural-physiognomic-floristic classification can be easily correlated with that of Webb (1968) at the subformation level because both systems use the same structural (height and leaf size) and physiognomic features (i.e. the presence of vines, palms, ferns, epiphytes and buttressing). The division of subformations into alliances and suballiances is based on floristic grounds. An alliance is defined as a group of vegetation units with similar key species in the dominant strata and of similar structure. Crown density is not used as a classification attribute in this system.

Suballiances are used as the basic vegetation classification units and, in this regard, are equivalent to associations in Beadle and Costin (1952) and forest types in FCNSW (1989). The definition of a suballiance used by Floyd (1990) differs, however, from that of an association of Beadle and Costin (1952). The suballiance permits the absence of some of the key species, and it applies to stages of rainforest succession rather than only to the climax stage. As suballiances are defined in order to represent ecological differences, they also differ in definition from forest types, which are weighted towards those vegetation units of high commercial value.

Wheat-belt region of NSW

Sivertsen and Metcalfe (1995) produced a vegetation classification for the southern wheat-belt area of New South Wales based on the system of Walker and Hopkins (1990). Two hundred and ninety sites were sampled, and analysed using cluster analysis from the computer software PATN, a multivariate analysis package developed by Belbin (1988, 1991). The locations and numbers of sampling sites were positioned to sufficiently represent each of the 'phototypes' which were recognised from API. On the basis of the cluster analysis and the consideration of structure, species composition and abiotic factors including soil type and altitude, 20 map units (site groupings) were identified within four broad geomorphic zones. These were mapped at a scale of 1:250 000.

3.1.3 Royal Botanic Gardens Sydney

The vegetation survey and mapping program of the Royal Botanic Gardens Sydney (RBGS) has been reviewed by Benson (1995). The vegetation is generally classified initially into structural formations using both height and PFC classes of Specht (1970), and then further divided into plant communities by the dominant or characteristic species of major strata. The classification was carried out from API with field checking. Areas of vegetation with similar structure and dominant species, and recognisable geological and landscape characteristics are grouped to form map units. Mapping in western NSW is at 1:250 000 scale, with three studies completed: Ana Branch-Mildura (Fox 1991), Balranald-Swan Hill (Scott 1992) and Booligal-Hay, Deniliquin-Bendigo (Porteners 1993).

The Sydney Region Vegetation Series are produced at 1:100 000 scale with six maps completed, Gosford-Lake Macquarie (Benson 1986), Katoomba (Keith and Benson 1988) Wallerawang (Benson and Keith 1990), Penrith (Benson 1992), Sydney (Benson and Howell 1994) and Burragorang (Fisher *et al.* 1995). Surveys and maps were also produced for the Brisbane Water National Park (Benson and Fallding 1981) and Merriwa area (McRae and Cooper 1985). All these maps show cleared areas, and delineate existing vegetation communities (natural vegetation) in the remaining parts of the study area.

The plant communities of the Monaro Lakes area, and the native grasslands of the Monaro region, have been classified and described by Benson and Jacobs (1994) and Benson (1994) respectively. The classification involved intensive floristic data analysis using the hierarchical classification software package PATN. The identified communities were not mapped in either study. In addition, the RBGS has completed similar studies for the Guyra and Ashford 1:100 000 mapsheets of the Northern Tablelands and North Western Slopes regions respectively.

3.1.4 Department of Land and Water Conservation

Department of Land and Water Conservation (DLWC) is managing the Murray Darling Basin vegetation mapping project using a modification of Walker and Hopkins (1990). The project involves the Commonwealth, New South Wales, Australia Capital Territory, Victoria, South Australia and Queensland governments. It aims to produce broad structural woody vegetation classes comprising vegetation type (only to genus level), growth form and density (crown cover) at a scale of 1:100 000, mainly based on the interpretation of satellite images supplemented by API and field data (Ritman 1995). Height is not used as an attribute in discriminating vegetation types. The structural vegetation data are stored as classes in the GIS. Outputs of the landcover, vegetation type, vegetation density classes, and forest extent can be produced from the GIS.

3.2 Queensland

3.2.1 Queensland Herbarium

The Queensland Herbarium (BRI) was part of Queensland Department of Primary Industries (QDPI) up until April 1992, but since that time has been part of Queensland Department of Environment and Heritage, now Department of Environment. A comprehensive review of the vegetation survey and mapping studies conducted by the Queensland Herbarium and methods adopted was produced by Neldner (1993).

In most BRI surveys, the vegetation classification is based firstly on life form and structure using height and PFC classes of Specht (1970), and secondly on floristics for the dominant species in the overstorey and associated species in the understorey (Neldner 1993). While Specht (1970) classifies vegetation on the basis of the tallest stratum, BRI uses the characteristic stratum, which is the layer that contributes most to overall biomass (Neldner 1993). A tree is defined as a woody plant >5 m tall with a single stem and shrub is a woody plant <8 m tall either multi-stemmed or branched close to ground level.

The basic unit in the BRI vegetation classification is the plant association defined by Beadle and Costin (1952). Associations are produced on the basis of the presence and abundance of species, the stratification of plant forms and the spatial distribution of individuals. They are described by structural data on the height, projective foliage cover and stem density of each structural layer, and a list of the most frequent species in each layer. A map unit may consist of one or several plant associations.

The Queensland Herbarium's involvement in vegetation mapping began with the involvement of staff firstly in the CSIRO Land Research Series, and later the QDPI WARLUS, land system survey and mapping. BRI botanists were involved with CSIRO surveys in the Nogoa-Belyando (Pedley 1967) and Balonne-Maranoa (Pedley 1974) areas. BRI botanists were involved in all six WARLUS studies, which covered a large proportion of inland Queensland: Boyland (1974, 1980), Beeston (1978), Purdie (1990), Purdie and McDonald (1990) and Turner *et al.* (1993). A vegetation map at a scale of 1:1 000 000 for all these areas was derived from the larger scale land system map (1:500 000) without reinterpretation of the aerial photographs for vegetation survey and mapping. A 1:2 000 000 vegetation map of Cape York Peninsula was derived from interpretation of large photo mosaics which were used for the Atlas of Australian Soils mapping by Pedley and Isbell (1971).

The Vegetation Survey of Queensland began in 1978, and aims to survey and map the vegetation of the whole State, producing maps at 1:250 000 and 1:1 000 000 scales. Queensland was divided into nine regions; maps and associated explanatory texts have been completed for four regions, South Western Queensland (Boyland 1984), South Central Queensland (Neldner 1984), Central Western Queensland (Neldner 1991), and Far Northern Queensland (Cape York Peninsula) (Neldner and Clarkson 1995, in press; Clarkson and Neldner in press). This program aims at mapping vegetation as it was at the time of European settlement (i.e. pre 1750). In disturbed areas, the vegetation is mapped from remnants and the analysis of the ecological factors of climate, soil and landform to determine the original vegetation. In the areas covered by land system mapping, the site data from these studies was supplemented with additional sample sites, and the land system boundaries were modified for vegetation mapping using API. The survey procedure consisted of preliminary field observations, photo-interpretation, reconnaissance phase, revision of photomapping, detailed field sampling, interpretation of boundaries, boundary and legend check, additional field sampling and finalising vegetation boundaries. The Cape York Peninsula survey was conducted from first principles, as there were limited reliable site data and mapping available for the area.

All Vegetation Survey of Queensland studies provide both a structural (formations) and dominant floristic classification (e.g. units dominated by *Acacia aneura* have the same cartographic screen). Map units are also combined into the higher level classification of broad vegetation groups (BVGs), to allow for national and regional analyses. BVGs encompass vegetation types that are frequently dominated by a single species, e.g. *Melaleuca viridiflora* or suite of species, e.g. the box eucalypts. Other groups are dominated by a structural formation (e.g. open heaths, closed forests of the Wet Tropics region). Specialised habitats such as the coral islands and intertidal areas form other groups. A series of tables in the GIS allows the user to easily produce maps based on either the structural formation, map unit or BVG (Neldner and Clarkson 1995). The relative numbers of classification units in each of these classification levels is shown in Table 8.

Table 8. Number of classification units in Vegetation Survey of Queensland studies

Study area	Associations	Map units	Structural formations	Broad vegetation groups	Reference
South Western Qld	67	31	14	8	Boyland (1984)
South Central Qld	167	73	26	14	Neldner (1984)
Central Western Qld	113	51	17	11	Neldner (1991)
Cape York Peninsula	309	201	21	30	Neldner and Clarkson (1995, in press)

The Moreton Region Vegetation Map Series concentrated on the densely populated southeast corner of Queensland. Four maps at 1:100 000 scale were produced as part of this study, Brisbane (Dowling and McDonald 1976), Beenleigh (Elsol and Dowling 1978), Caloundra (Elsol and Sattler 1979) and Murwillumbah (McDonald and Whiteman 1979). The mapping scale for this study was then changed to 1:250 000, and three map sheets have been worked on at this scale, Warwick (Young and McDonald 1989), and Ipswich (Elsol 1991).

In recent years, a large amount of work has been conducted in southeast Queensland as part of the mapping and survey of Eastern Queensland. Existing vegetation is mapped at 1:100 000 scale using a combination of aerial photographs and current LANDSAT imagery. Pre- 1750 vegetation is also mapped using API and sampling of remnants (Thompson *et al.* 1996).

Vegetation mapping at 1:250 000 scale has been finalised for five sheets in the Desert Uplands (central Queensland) and commenced for the Einnasleigh Uplands (north Queensland). A variety of large scale mapping projects have been completed (see Neldner 1993 for details).

3.2.2 Queensland Department of Primary Industries Forestry

There is limited published information on the forest classification and mapping conducted by Queensland Department of Primary Industries (QDPI) Forestry (formerly Department of Forestry and Queensland Forest Service). According to QDF (1986), one of the few published references dealing with this forest type classification, the forests in Queensland were divided into eight broad types: tropical rainforests, subtropical rainforests, wet sclerophyll forests, dry sclerophyll forests, sclerophyll woodlands, cypress woodlands, *Acacia* and *Casuarina* scrubs, and tidal swamp forests. QDPI Forestry has extensively mapped from API broad vegetation types by dominant species, with a bias toward commercial species, at the 1:50 000 scale. This mapping is still in use for the purposes of yield calculation and commercial forest operations (per. comm. Phil Norman, Queensland Department of Natural Resources).

QDPI Forestry is currently incorporating a classification system modified from Walker and Hopkins (1990) into its inventory procedure, with each forest unit being described by both structure and floristics (for dominant overstorey species) (Preston 1989). For non-rainforest forests, both the crown cover classes for tree growth forms and height classes are similar to

Walker and Hopkins (1990). The classification is a two-level hierarchical system consisting of structural formation and forest type. The name of a non-rainforest type has three components: key species (the most abundant or physically predominant species in the tallest stratum), height and crown density (e.g. spotted gum open forest).

The rainforest description is simplified from Walker and Hopkins (1990) to allow for maximum use of API and the limited botanical training available to field staff. The term "rainforest" is not used in the naming of forest types in this classification, with most rainforests described as closed forests. Most QDPI forest mapping is at a scale of 1:25 000.

In 1995-1996, QDPI have been using API of recent colour photographs, forest type mapping, disturbance mapping from LANDSAT and field validation in an assessment of old growth forest in southeast Queensland. Forests identified as old growth have been related to the regional ecosystems of southeast Queensland listed in Young (1995).

3.2.3 Department of Environment

A variety of vegetation maps have been produced for National Parks (see listing in Neldner 1993) by the Department of Environment (DoE) (formerly Department of Environment and Heritage). Before 1984, DoE's vegetation classification and mapping was based on a combination of the structural characteristics of Specht (1970) and floristic information. Since 1984, it has been based on Walker and Hopkins (1990).

The concept of regional ecosystems has been used to provide a rapid assessment of the conservation status of Queensland's vegetation (Young 1995). Regional ecosystems are descriptions of the major types of vegetation and landform present within biogeographic regions. They reflect the relationship between canopy species and environmental variables, in particular, geology, rainfall and landform at the regional scale with an emphasis upon localised but distinctive floristic assemblages (Young 1995). For example, the regional ecosystem "lowland rainforest" reflects complex notophyll rainforests associated with warm and moist/wet climate, <600 m altitude, and high fertility and/or deep soils derived mostly from intermediate and basic volcanics.

Regional ecosystems generally correspond to vegetation and/or land system mapping units. Where a consistent vegetation mapping coverage exists across a region (e.g. Cape York Peninsula), then vegetation mapping units are used as regional ecosystems. However where there is an inconsistent mapping approach or lack of data, then regional ecosystems are constructed from the available vegetation and land system mapping, other environmental attribute mapping and manual interpretation of LANDSAT imagery. The regional ecosystems will continue to be revised as new mapping becomes available (Young 1995).

The regional ecosystems are being adopted by the Queensland Department of Natural Resources for the Comprehensive Regional Assessment (CRA) Program in southeast Queensland (pers. comm. Alf Said, Queensland Department of Natural Resources, Brisbane).

3.3 Victoria

3.3.1 Department of Natural Resources and Environment

The public forest lands in the East Gippsland area of Victoria were mapped by the Forests Commission of Victoria (FCV) using a classification based on dominant overstorey species, life form and the structural system of Specht (1970) (Woodgate *et al.* 1994). While the PFC classes adopted are the same as Specht (1970), modified height classes are used, i.e. four height classes for trees (>40 m, 28-40 m, 15-28 m, 5-15 m) and two classes for shrubs (2-8 m, <2 m). Forest types are the basic classification units and are mapped at a scale of 1:63 360 using API with intensive ground truthing (Buntine 1974). Detailed information on the classification results are well illustrated in a series of reports for land use surveys by the Land Conservation Council (LCC 1974, 1977, 1982, 1991).

Several other vegetation classification and mapping systems have been used by the Department of Natural Resources and Environment (DNRE) (formerly Forests Commission of Victoria and Department of Conservation & Natural Resources) for different study purposes, notably floristic vegetation communities and ecological vegetation classes.

Floristic vegetation communities

This is basically a floristically orientated system in which two important structural attributes, height and crown density, play limited roles in classifying vegetation types. The system was used by Forbes *et al.* (1981) to classify plant communities in the Gippsland Lakes catchment and East Gippsland, and has since been used elsewhere. The system involves detailed floristic analysis of numerous survey quadrats using a computer-based numerical classification program and a hand-sorting method outlined in Gullan (1978) and Gullan *et al.* (1981). Initially, the results from the numerical analysis are placed into a two-way matrix table in which columns contain a list of all the species found in one quadrat and a row indicated all the quadrats in which one species had been found. In this table, quadrats are subjectively hand sorted based on the principle that quadrats sharing a large number of species, in both upper and lower layers, are placed together. The final classification is then determined from such sorting.

The sub-community is the basic unit of vegetation, and is defined as a group of quadrats which have a similar floristic composition. A community is a collection of sub-communities which have floristic and environmental affinities. The community name consist of three parts: environment, life form and structure, such as montane sclerophyll woodland or coastal sclerophyll forest. As reflected in the names, this system aims to describe the complex relationship between the physical environment, vegetation and the landscape. Under this classification, a community may represent a floristic continuum, or a group of sub-communities exhibiting a different structure which is considered to be a single vegetation type under different disturbance regimes.

Forbes *et al.* (1981) analysed 1312 survey sample quadrats from the East Gippsland area. As a result, 13 floristic vegetation communities were recognised in the Gippsland Lakes Catchment and 21 in East Gippsland with lowland sclerophyll forest and damp sclerophyll forest being the most extensive communities. Based on this plant community information, Parkes *et al.* (1984) produced a 1:250 000 floristic vegetation community map for East Gippsland using API plus extensive field checking.

Ecological vegetation classes

This relatively new classification system was developed from the vegetation classification of floristic communities described by Forbes *et al.* (1981) and was one of the outcomes of the study of the old-growth forests of East Gippsland conducted by DNRE (Woodgate *et al.* 1994). Ecological vegetation classes (EVCs) consist of one or a number of floristic communities that exist under a common regime of ecological processes within a particular environment at a regional, State or continental scale (Woodgate *et al.* 1994). In contrast to formations and floristic communities, EVCs are defined at a qualitative level by both their floristics and structure, and linked to the broad landscape features (e.g. coasts, plains, mountains) and their respective climates. This link is reflected in EVC nomenclature, e.g. coastal grassy forest and montane wet forest. Floristic communities that have very few species in common but respond to a similar environmental regime may be placed into the same EVC, while other EVCs may consist of only one or a few specialised floristic communities. Vegetation mapping was important for the study of old-growth forests of East Gippsland, as it provided an ecological context for stands of old-growth forest, and thus allowed a more refined and focused management response for areas of old-growth forest.

Vegetation on public land in East Gippsland was classified into 44 ecological vegetation classes. These classes were then grouped into 20 vegetation groups and mapped at a scale of 1:100 000. The ecological vegetation classification was undertaken by overlaying information about the physical environment, biogeography and existing floristic quadrat information onto forest type maps (Woodgate *et al.* 1994).

A new forest mapping program

Currently, DNRE is undertaking a Statewide forest classification and mapping project, a component of DNRE's Statewide Forest Resource Inventory Program, using a system based on a modification of Walker and Hopkins (1990). DNRE (1996) has defined a set of stand classes of species and structure (height and density) for forest type classification. For eucalypt forest, there are six height classes: >51.0 m; 40-50.9 m; 28.0-39.9 m; 15.0-27.9 m; 5.0-14.9 m; and <5.0 m. Unlike the system used by the former Forests Commission of Victoria, this program uses crown cover and crown form instead of PFC in describing crown density. There are six crown cover classes: 85-100% (very dense); 70-84% (dense); 50-69% (medium); 30-49% (low); 10-29% (sparse); and 1-9% (very sparse). Note that the classes are different from those of Walker and Hopkins. Crown form is the basic condition of the eucalypt crowns within the stand and is categorised into three types: irregular, regular and regrowth. DNRE (1996) aims to map forest types at a scale of 1:25 000.

3.3.2 Land Conservation Council

As part of a revision of the forest types mapped by the Forests Commission, Land Conservation Council (LCC) has undertaken comprehensive studies to describe and assess the natural resources of public land in eastern Victoria using a system consisting of structure and floristics (LCC 1974, 1977, 1982).

Vegetation is classified into a two-level hierarchical system: (1) structural form and (2) vegetation unit. The structural form is based on the life form, height and PFC of the tallest stratum using a modified version of Specht (1970). There are four height classes (>40 m, 28-40 m, 15-28 m and 5-15 m) and three PFC classes (>70%, 30-70%, 10-30%). Within each structural form, vegetation is subdivided into different species associations (vegetation types) based on commonly occurring

combinations of species of the dominant stratum (the one that exerts a controlling influence on other plants, usually the tallest stratum).

In the LCC studies (1974, 1977, 1982) eastern Victoria was divided into three study areas: East Gippsland, the Alpine area and the Gippsland Lakes hinterland area. Thirty vegetation types were recognised in both the East Gippsland and the Alpine study areas, and 31 types were identified in the Gippsland Lakes hinterland. These vegetation types were mapped at a scale of 1:100 000 on the basis of API, extensive ground truthing and the use of existing references.

3.4 South Australia

3.4.1 Department of Primary Industries Forestry

The system used by the Department of Primary Industries (DPI) Forestry for classifying forest types of South Australia is based on structure and floristics. The attributes used in the classification are life form (tree, shrub, grass, etc.), height, PFC and species composition (the relative proportions of the major species present). Vegetation is divided into formations and then subdivided into forest types, the basic classification unit in this system. A formation is defined as a group of plant communities which have the same basic structure of life form, height and PFC (such as forest, woodland, grassland, etc.), and the classification is based on Specht (1970). A forest type is directly referable to its formation and dominated by one or more species in the overstorey (such as pink gum woodland type). As noted by Boomsma and Lewis (1981), this two-level hierarchical classification system is adopted for the practical reason that the structural formation and forest type are readily defined and recognised in the field.

Using this system, the vegetation of South Australia is divided into nine formations which are open forest, low open forest, woodland, open woodland, low woodland, low open woodland, open scrub, tall shrubland and tall open shrubland. These formations consist of 336 vegetation types. DPI Forestry has produced a 1:2 000 000 natural vegetation map of South Australia showing the distribution of the nine formations, based mainly on previously produced maps. The reasons why only the formations are mapped are the small scale of the map, and because formations are considered to be sufficient for forest management purposes (Boomsma and Lewis 1981).

3.4.2 Department of Environment and Natural Resources and Department of Housing and Urban Development

In South Australia, vegetation classification and mapping projects (approaches) are coordinated through the Biological Survey Coordinating Committee. The principal agencies involved are the Department of Environment and Natural Resources (DENR) (previously the Department of Environment and Planning) and the Department of Housing and Urban Development (DHUD). Within these agencies there is both a structured approach to classification and mapping, according to the requirements (objectives) of the various section, and in some cases an opportunistic approach (DHUD 1995). In terms of responsibility DHUD principally works on vegetation classification and mapping in the southern agricultural region of the State, while DENR works in both the northern pastoral region and the southern agricultural region.

In reference to the structural classification approach, a cluster analysis using PATN, which analyses vegetation based on plant species composition (floristics) is used. Plant species are generally weighted according to adapted Braun-Blanquet cover/abundance scores, but in some earlier studies only presence/absence of plant species was involved. The communities are classified to reflect floristics with either species cover/abundance or presence/absence and these are correlated with environmental changes such as drainage, local topography, micro-climate and fire history (Goodwins *et al.* 1989). Dominate species and species association are determined by both field observation and objective computer-based pattern analysis. Naming and describing the groupings resulting from the analysis involves the use of floristics with overstorey structural information (height and PFC based originally on Specht classes). Currently the structural formation classes are adapted from Specht (1970) and Muir (1977).

Vegetation classification has been completed for some regions. These include Mt Lofty Ranges (Goodwins *et al.* 1989), Yellabinna (Copley & Kemper 1992), Messent Conservation Park (Owens *et al.* 1995a), Yumbarra Conservation Park (Owens *et al.* 1995b), Western Murray Flats (Lock and Goodwins 1994, Playfair and Heard 1994, 1995), Murray Mallee and South East (Heard 1995). Mapping occurs also for these regions with the exception of Gawler Ranges and the Nullarbor areas. Only localised areas around survey locations were mapped for both these regions.

In this structural approach the vegetation communities are mapped at 1:40 000 scale in the southern agricultural districts using API, combined with extrapolation of the site survey analysis and further ground truthing (Heard 1995). In the northern pastoral region the structured mapping approach uses 1:84 000 - 1:86 000 colour aerial photography, black and white 1:100 000 scale photo mosaics or hardcopy geo-rectified Landsat (TM or MSS) imagery, and site survey analysis (Forward 1995, Gould 1995). Digital image analysis is being investigated for the vegetation mapping in the north of the State (Hart 1995).

An opportunistic approach is also used in classification and mapping, for example pastoral assessment for land system mapping, in vegetation clearance assessment and in off-park or on-park conservation assessment. Vegetation types are assessed subjectively under these conditions, based on the dominant overstorey and dominant understorey with descriptive structural terms based on Specht (Gould 1995, Carruthers 1995, Kinnear 1995).

All spatial data collected, such as digitised vegetation mapping boundaries, landsystem mapping and land cover mapping, are stored on GIS and the textual data are stored in ORACLE, a relational database. Both the GIS and the textual databases are maintained by DHUD.

3.5 Western Australia

3.5.1 Conservation and Land Management

The forest type classification system adopted by Conservation and Land Management (CALM) in southwest Western Australia uses both structure and floristics (McNamara 1959, CALM 1992, Bradshaw *et al.*, in prep). The description of floristic composition is mainly confined to the overstorey, while the height is classified using separate height classes for wet and dry sclerophyll forest. Forest form is recorded as sapling, pole, and massed forest; crown cover density is classified according to upper strata density; and total stand density is recorded. Several kinds of

vegetation maps that have then been produced based on: floristic composition, height, forest form, upper strata density, and total stand density. These maps are at a scale of 1:25 000 based on API of 1:15 840 scale photos with ground truthing and stored digitally within a GIS.

The major forest area in Western Australia is in the south-west corner of the State. Here, CALM has classified the forest type of all public forested and much of the private forested land. Eucalypt species that constitute greater than 20% of the total are recorded in order of dominance. For broad descriptive purposes five major forest types are recognised according to the dominant species: Jarrah (*Eucalyptus marginata*), Karri (*E. diversicolor*), Wandoo (*E. wandoo*), Mallet (*E. astringens*, *E. gardneri*, *E. falcata* and *E. spathulata*) and Tuart (*E. gomphocephala*) (Harris 1956, CALM 1992). The Jarrah and Karri forests are dominant types both in terms of area and use, and are a focus of CALM's forest management strategies (CALM 1992). Five height classes are recognised in Jarrah, Wandoo, and Blackbutt (*Eucalyptus patens*), and three classes in Karri. There are nine upper strata density classes for Karri and six for all other forest types, while nine total stand density classes are identified for all forest types (Bradshaw pers comm CALM).

CALM has also used other vegetation classification systems in specific projects and within individual forest types, particularly in Jarrah forest. Havel (1975a, 1975b) developed a comprehensive land attribute and vegetation classification system in a study of Jarrah forests in the north and central forest regions of southwest Western Australia. Havel's system used ordination of the site floristic data and expert knowledge to group vegetation mainly on indicator species, which are largely found in the understorey. The site-vegetation groups identified were related to environmental attributes of soils, geomorphology and climate. Vegetation was considered to be the integrator of all the site characteristics such as fertility, moisture and drainage (Havel 1975a). For the tree stratum, he described height class and basal area class, and included a brief floristic description of species in addition to the indicator species. Havel's approach has since been extended to other areas of Jarrah forest by Strelein (1988). Havel (1975b) described 19 site-vegetation types for northern Jarrah forest and Strelein (1988) recognised 17 such types in southern Jarrah forest. These types were not mapped in either study.

Heddlé *et al.* (1980) produced vegetation complex maps for the Darling District area of Western Australia based on the landform-soil units mapped by Churchward and McArthur (1980). The site-vegetation types defined by Havel (1975a, 1975b) and the vegetation map units of Smith (1974) were related to these mapped vegetation complexes in tabular form. Twenty-eight vegetation complexes, which equate to largely to land systems, were recognised in the area. The maps depict the original native vegetation as it existed before European settlement. In cleared areas, the original vegetation was reconstructed from remnant vegetation.

3.5.2 Department of Agriculture

The Department of Agriculture initiated a vegetation survey of Western Australia in the early 1970s. Vegetation communities were mapped at 1:250 000 scale using API, and a classification based on the structural formations of Specht (1970) and dominant floristics. Three sheets were mapped: Pemberton and Irwin Inlet (Smith 1972), Busselton and Augusta (Smith 1973) and Collie (Smith 1974). When the Department stopped the project, John Beard continued the vegetation mapping of the State.

The Department of Agriculture has adopted a site type classification approach in studying the remnant forests on agricultural land. The system aims to reflect interrelationships between the physical environment and plant communities. A site type is defined as 'a kind of land with

specific physical characteristics which differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its response to management' (Pringle *et al.* 1994). This definition is equivalent to the 'ecological site' concept of the Society for Range Management (1991). The site type classification is carried out primarily through numerical analysis of site information on land surface and dominant species, under certain patterns of grazing impact. The two most used structural attributes, height and density, are not used in this classification system. The classification consists of two hierarchical levels, site type group and site type. The allocation of site types into site groups is based on dominant vegetation components, position in the landscape, landform and soil types as reflected by the names of the site groups, e.g. 'sandplain spinifex hummock grasslands and *Acacia* shrublands on deep sandy soils'. In this classification system, a tree is defined as a plant with a height > 2 m and a single trunk to at least 1.5 m.

The classification system is at landform/plant community scale and is well illustrated in the survey of the northeastern goldfields (Pringle *et al.* 1994). The survey involved both reconnaissance field work and intensive site sampling, and resulted in 1:250 000 land system maps for the region. A total of 724 inventory sites representing different land systems identified from existing aerial photographs were recorded. The data collected were analysed using a number of multiple-variable analysis and statistical software packages including PATN and SYSTAT. Thirty-six site types were recognised in the survey area, and these were then grouped into seven major site type groups.

3.5.3 Beard's vegetation mapping in Western Australia

Beard has produced a series of 1:250 000 of natural vegetation maps of southern Western Australia (e.g. Beard 1979b) and 1:1 000 000 maps of the rest of Western Australia (e.g. Beard 1982), based on both structural and floristic information. Although the author does not belong to either CALM or the Department of Agriculture, the two major forested land management agencies in Western Australia, his work is worth discussing because it was undertaken across the whole State. The basic unit of the classification is the floristic plant association, which is defined as the largest possible group with consistent plant dominants (Beard 1979a, 1980). Plant associations are grouped floristically into alliances, and structurally (height and density) into formations, as defined by Specht (1970). However, PFC refers to the "dominant" stratum differing from the "tallest" stratum of Specht (1970). All data used for the classification and mapping are digitised and stored in a GIS database of Western Australia's Department of Agriculture. Beard's maps are used by CALM in the management of areas outside the southwest.

3.6 Tasmania

3.6.1 Forestry Tasmania

Forestry Tasmania (formerly Forestry Commission of Tasmania) uses a commercially oriented forest type classification system, similar to that adopted in forestry agencies in New South Wales and Victoria, for classifying and mapping the forests of Tasmania. The forests are classified firstly into three categories: eucalypt forest, rainforest, and miscellaneous including forest dominated by secondary species. Eucalypt forests are divided into two groups on the basis of forest age: mature eucalypt (>110 years old) and eucalypt regrowth (<110 years old). Each group is further divided into several height and crown density classes (Table 9). There are four divisions within rainforest: large crowned rainforest 25 m or greater in height, small crowned <25 m, Myrtle

(*Nothofagus cunninghamii*) regrowth <15 m, and Myrtle regrowth 15 m or greater. This is basically a structural classification with few floristic attributes and is based on crown density and height classes which contain more levels than those of Specht. Forestry Tasmania also uses floristic classifications (e.g. Pannell 1992, Kirkpatrick *et al.* 1988, Duncan and Brown 1985) for ecological/conservation orientated purposes.

Table 9. Height and density classes adopted by Forestry Tasmanian

Height* (m) classes		Density (% crown cover) classes	
Mature eucalypt	Eucalypt regrowth	Mature eucalypt	Eucalypt regrowth
>76	> 50	70-100	90-100
55-76	44-50	40-70	70-90
41-55	37-44	20-40	50-70
34-41	27-37	5-20	10-50
27-34	15-27	<5	1-10
15-27	<15		
<15			

* Based on average height

A vegetation map of Tasmania has been produced at a scale of 1:500 000 using the forest type mapping, additional API and extensive field validation (Kirkpatrick and Dickinson 1984), and is stored in digital form in the Forestry Tasmania GIS. This has been updated for forests by Kirkpatrick and Brown (1991) for the Resource Assessment Commission (RAC) and is held by Forestry Tasmania and the National Forest Inventory.

3.6.2 National Parks and Wildlife Service of Tasmania

The National Parks and Wildlife Service of Tasmania has undertaken a number of vegetation studies in Tasmania including those of rainforests (Jarman *et al.* 1984); cool temperate rainforest (Jarman and Brown 1983); plant communities containing tree ferns (Neyland 1986); and dry sclerophyll forest (Duncan and Brown 1985). These classifications are based on physiognomy, species dominance in the tallest stratum and life-form dominance in the lower strata. However, the outcomes of the classifications are not mapped.

Jarman and Brown (1983) believed that the widely accepted definition of rainforest as 'closed forest' does not suit cool temperate rainforest in Tasmania well because the definition excludes the more open communities in scrub and alpine rainforests and does not distinguish between rainforest character and those of a more sclerophyllous nature. They defined cool temperate rainforest in Tasmania as those forest communities which are taller than 8 m and dominated by species of *Nothofagus*, *Atherosperma*, *Eucryphia*, *Athrotaxis*, *Lagarostrobos*, and *Phyllocladus*.

Duncan and Brown (1985) produced a classification of the dry sclerophyll vegetation of Tasmania. The classification involved 1679 plots located subjectively across all dry sclerophyll vegetation areas in the State. The floristic (both overstorey and understorey) data recorded from these plots were subjected to numerical analysis using the programme DIVINF described by Dale *et al.* (1979). On the basis of the analysis and expert knowledge, 33 plant communities were recognised. These plant communities were then aggregated into six dry sclerophyll groups based on the structure and dominant life form of understorey. For example, plant communities with trees 12-25 m in height and with sedges dominating the ground layer were placed into the 'grassy' group.

The wet eucalypt forests of Tasmania were classified by Kirkpatrick *et al.* (1988). These forests have subordinate strata dominated by rainforest trees, broad-leaved shrubs, sclerophyllous shrubs or ferns. Survey quadrat-based floristic data were subjected to an intensive computer-based numerical analysis using the program TWINSpan, a two-way indicator species analysis software package, which uses species presence and absence as input for the analysis (Hill 1979). Plant communities were selected based on the principle that a community needed to have two or more constant species to discriminate it from similar communities. Communities which share a particular eucalypt species were then aggregated into four structural/physiognomic types based on the height of the dominant stratum, and the life form in the understorey stratum. The four types are subalpine wet sclerophyll forest (< 30 m), subalpine mixed forest (dominant stratum < 30 m), wet sclerophyll forest (> 30 m) and mixed forest (> 30 m). Thus within any community there may be variation in structure and in the dominance of lower strata. Crown density is not used in discriminating vegetation types. Kirkpatrick *et al.* (1988) used the quadrat data to provide distribution maps (based on a 10 x 10 km grid) for each TWINSpan group of the wet sclerophyll forest associations in Tasmania.

3.7 Northern Territory

The vegetation classification used by Conservation Commission of the Northern Territory, now Parks and Wildlife Commission of the Northern Territory (PWCNT), in the 1:1 000 000 vegetation map of the Northern Territory was based on the structure of major strata combined with dominant and/or characteristic species from each layer (Wilson *et al.* 1990). The structural classification was a modified version of Specht (1970), in which there are three height classes (10-30 m, 5-10 m, < 5 m) and four projective foliage cover classes (70-100%, 30-70%, 10-30%, 1-10%). Floristically, a plant community is considered to have a consistent floristic composition in at least the dominant stratum. For example, the *Allosyncarpia ternata* closed-forest is a community that has a closed-forest structure (height 10-30 m, PFC 70-100%) and is dominated by *Allosyncarpia ternata*. The classification system has two levels: formation and plant community. The latter is an equivalent unit to the plant association of Beadle and Costin (1952).

The floristic data (presence/absence of perennial species only), was differentiated into upper and lower storey plants, and those occurring north and south of 18 degrees latitude south. The four separate databases were analysed using TWINSpan. Ninety-two groups were derived. These groups were related to the vegetation mapping units, which were derived from the interpretation of satellite images with intensive field checking. There were 112 vegetation mapping units (7 forest, 55 woodland, 50 shrubland and grassland) which were grouped into 12 formations. Understorey species were also used in the classification at formation level. For example, *Eucalyptus* forests were divided into two formations, *Eucalyptus* with grass (mainly sorghum) understorey and *Eucalyptus* with hummock grass understorey.

PWCNT have also completed land system/ vegetation mapping surveys in national parks (e.g. Sivertsen and Day 1985), pastoral properties (e.g. Day *et al.* 1979), proposed mining areas (e.g. Day and Czachorowshi 1982) and regional areas (e.g. Aldrick and Wilson 1990). The focus of these studies has been on landsystem mapping using API, sometimes with reference to satellite imagery. Vegetation maps at 1:100 000 scale have been derived from the landsystem mapping in some areas (e.g. Sivertsen and Day 1985). The structural classification generally used is Specht (1970), although some studies have used Walker and Hopkins (1990).

There have also been a number of studies in the Northern Territory where a floristic classification has been produced based on TWINSPAN analyses, e.g. monsoon rainforest patches (Russell-Smith 1991).

3.8 Australian Capital Territory (ACT)

In the Australian Capital Territory (ACT), ACT Forests (ACTFS) manages all forest plantations, while the Parks and Conservation Service is responsible for other forested lands. An ACT vegetation classification was carried out on the basis of several existing maps, in addition to a slightly modified scheme of Specht, using structure (height and PFC of the tallest stratum) plus floristics (Wells *et al.* 1989). Classification was based on API in the early times. More recently, for some specific areas including Jervis Bay, Cotter Catchment and Mt Ainslie and Mt Majura, Tidbinbilla Nature Reserve and Mt Tennant, it has been based on intensive field surveys using site quadrat biotic/abiotic attribute data. The maps produced vary in quality, extent and scale (1:25 000 to 1:100 000). Floristics have become a strong component in more recent vegetation classifications and in current mapping projects. In the Jervis Bay vegetation classification and mapping project, classification by cluster analysis and modeling against topography was also used.

4. Discussion

4.1 Vegetation classification systems for wood production management compared with those for conservation and environment management

A summary of the classification and mapping systems used by the various State and Territory agencies in Australia for different management objectives is given in Table 1. The relationships between these systems is illustrated in Fig. 1.

Overall, there are two types of classification systems developed to match the end use, one for wood production management and one for conservation and environment management. Forestry management agencies are the departments, commissions or services responsible for managing publicly owned forested land for multiple uses including wood production, conservation, recreation and protection of watersheds. Conservation and environment management agencies are the departments or services responsible for managing publicly owned land, including forested land, primarily for conservation and environment management.

Most agencies use structure and floristics as important components of their vegetation classification and mapping systems. However, classification and mapping systems for wood production purposes differ from those for conservation and environment management in several aspects - in their treatment of ecology, vegetation coverage, and use of understorey species in classifications.

4.1.1 Emphasis on ecology

In general, classification systems for conservation and environment management emphasise ecological aspects and provide more comprehensive descriptions of vegetation types than those used for wood production purposes. Systems used for wood production management tend to concentrate on commercially important tree species. Forest classifications for wood production management are based on vegetation structure and common dominant overstorey species, often of commercial importance. In such classifications species relationships, a major criterion used in the classifications for conservation and environment management to define forest communities, are not always used in discriminating forest types. Vegetation units of lower commercial value may be amalgamated. For example, New South Wales Myrtle forests are classified into a single forest type of little commercial value in the classification for wood production management (FCNSW 1989), but into seven suballiances in Floyd's ecological classification (Floyd 1990).

As a result of this difference, classifications for wood production purposes may vary in species composition, structure and extent from that for conservation and environment management. In Tasmania, eucalypt forests are classified for wood production purposes as mature or regrowth, and then subdivided into several height and PFC types. Under the classification system for conservation planning, which is based on the principle that a community needs to have two or more constant species to discriminate it from similar communities, the same eucalypt forests are classified into several community groups and a number of plant communities. This latter type of classification system is useful for the conservation and environmental management of forests, particularly when used in conjunction with a knowledge of key environmental factors.

4.1.2 Coverage of vegetation types

Because of their different management aims, forest agencies have developed vegetation classification systems specifically for forested land, while conservation and environmental agencies consider all vegetation types, including woodland and grassland, equally. For example, Forestry Tasmania has divided the commercially important eucalypt forests of Tasmania into several divisions and subdivisions by age and height, aspects which are most relevant to the utilisation of timber. Other vegetation types, such as forest dominated by secondary species, have received little attention for wood production purposes, but are used for conservation planning. The Tasmanian NPWS has undertaken intensive vegetation classifications of cool temperate rainforest, wet eucalypt forest, dry sclerophyll forest and other vascular plant communities. In Queensland, the Queensland Forest Service conducts most of its forest type mapping in forests that have commercial potential, while the Queensland Department of Environment is undertaking classification of all types of vegetation in the State. Similar situations exist in New South Wales and South Australia.

4.1.3 Use of understorey species

Vegetation classification systems employed by land managers are chosen to provide adequate information both efficiently and effectively. Thus different systems will be selected to meet different objectives.

Incorporating understorey species into a vegetation classification system usually permits vegetation units to be discriminated on a finer ecological scale than is expected if only overstorey species are used. Within a forest, understorey species may characterise more subtle variations in environments than overstorey species, as they may be responding to apparently quite different controlling environmental factors than the overstorey. In most classifications used for conservation purposes, species from both the overstorey and understorey strata are used in discriminating vegetation types. In contrast, the classifications for wood production purposes use only the dominant overstorey species.

When included in a numerical analysis, often only about 1/4 to 1/3 of understorey species finally contribute to the definition of vegetation units. The remainder either define patterns that are too broad or too narrow to be relevant at the level of "association".

The importance of understorey species thus relates to their capacity to define vegetation patterns or structures that are at a scale relevant to managers. These patterns may be important to the species used in the analyses or to other species which are highly correlated with the vegetation units in associated environments.

4.1.4 Number of basic vegetation classification units

The use of different vegetation classification systems may result in quite different classification outcomes for the same vegetation in terms of the number of vegetation units. For example, rainforests in New South Wales have been classified into:

- 6 alliances and 19 forest types by FCNSW (1989)
- 7 alliances and 15 suballiances by Beadle and Costin (1952)
- 13 alliances and 57 suballiances by Floyd (1990).

4.2 Classification systems for wood production purposes

Most forest classification systems used for wood production purposes are designed to efficiently emphasise commercially valuable species. However, there are still some differences between these systems, particularly in the use of structure and floristics.

4.2.1 Use of structure and floristics

With the exception of the Baur system, all classification systems are based on clearly defined height and crown density classes. While floristics play an important role in most of these classification systems, the forest type system used in Tasmania for wood production purposes uses a basic structural classification with few floristics. Because of these differences, the forest type Alpine Ash (*Eucalyptus delegatensis*) in SFNSW's system may be made up of forests dominated by alpine ash but with substantial variations in height. Victoria uses combination of four level height classes and three level PFC classes as forests dominated by alpine ash may be placed in different types and formations (such as open forest or woodland) according to their height and projective foliage cover. In Forestry Tasmania's classification for wood production, alpine ash forests may be grouped with forests dominated by other eucalypt species to form a structural forest type characterised by a certain height and crown cover. Such differences can be confusing if the outcomes from different methods are combined into one uniform classification. For example, the national vegetation map produced by RAC (1992) was designed to be floristically based but was derived, for the forests of Tasmania, from the structural forest typing used for wood production purposes.

4.2.2 Levels and ranges of height classes

Although the structural formations adopted in most vegetation classification systems used for wood production purposes are modifications of Specht (1970), there are differences in both the levels and ranges of height classes among these systems (Fig. 2). The differences in height classes used by different agencies may mean that a forest defined as a tall eucalypt forest in Victoria or Queensland would not be classified as tall forest in Tasmania. The differences are the result of ecological variations in the vegetation between different regions of the country, and the development of classifications that were relevant to the management of different forest types in different regions.

4.2.3 Crown density

Most vegetation classification systems for wood production purposes are developed based on the concept of PFC (Specht 1970) in describing crown density, but Queensland DPI Forestry uses the expression of crown cover of the Walker and Hopkins (1990) in its classification. Although the crown classes of Walker and Hopkins (1990) have been selected to coincide as closely as possible with Specht, they differ from PFC in definition, measurement and the levels of ratings (four levels for PFC while six for crown cover). In general, PFC varies with leaf area index, crown type and age. It can also be affected by drought. Furthermore, PFC for some eucalypt species changes with time of day and cannot be determined from remote sensing data (pers comm. John Benson, Royal Botanic Gardens, Sydney). The use of different methods (i.e. crown cover and PFC) may result in either the same outcome for different forests or quite different classification outcomes for the same forest. This is because forests with the same crown cover (crowns are treated as opaque) may have

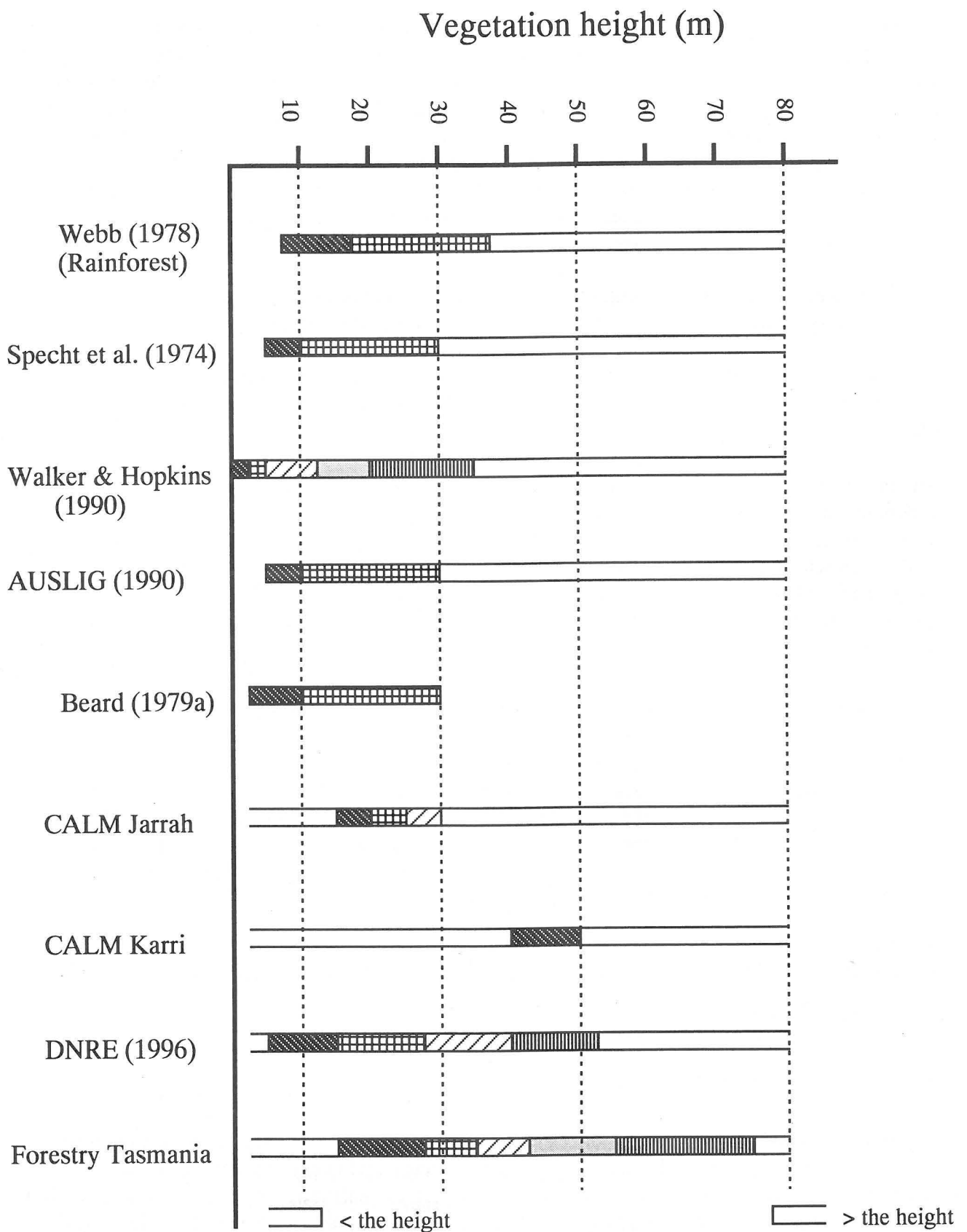


Fig. 2. Comparison of levels and ranges of height classes for tree-dominated communities in the major vegetation classification systems used in Australia

different PFC if they have different leaf area indexes. Therefore, it is likely that a “forest” with a low leaf area index in Queensland in QDPI Forestry’s classification system would be defined as an “open forest” in the Victoria’s system. The potential for classifying forests with different densities into the same category on crown cover and PFC can be minimised if crown cover is converted into percentage foliage cover by measuring crown type and using the formula provided by Walker and Hopkins (1990). Most classification systems, including those for conservation and environment management that use crown cover to define crown density, do not measure crown type. In general, crown cover has the advantage that it is more reliably mapped from API while in some areas and for some species, PFC can vary widely from season to season.

Agencies using crown densities also differ in the number of classes they employ: Victoria and South Australia - four PFC classes, Tasmania - five crown cover classes.

Although Specht’s (1970) original height and PFC classes have been modified to various degrees by some individual forest agencies, the PFC classes have not been modified as much as the height classes.

The differences in height and crown cover classes used in the different States and organisations highlights the importance of gathering measured data rather than classes if the task of combining data between agencies is to be expedited. With actual measurements, the sites can be relatively easily reclassified to other classification systems. While systems such as Beard and Webb (1974) and Carnahan (1976), and more recent systems such as NPWS (1995) of NSW and Ritman (1995), all record structural data for each polygon, the data recorded are still in classes, and hence do not allow the classifications to be easily altered for different thresholds.

4.2.4 The level of vegetation classification units used in management plans

Both the classifications used by Queensland and South Australia DPI Forestry, and CALM (WA) for wood production purposes, tend to use only the highest level of forest type classification, such as ‘wet sclerophyll forest’ (QDPI Forestry Service), ‘open forest’, and ‘jarrah forest’ (CALM) in their broad management plans, though detailed levels of classification are used for management prescription. For SFNSW and Forestry Tasmania, forest type is used as the basic vegetation classification unit in wood production management plans.

4.3 Classification systems for conservation and environmental management

4.3.1 Classification systems

A common goal of all conservation and environment agencies is to classify vegetation types to reflect the complex ecological relationships among species, and between plant species and environmental factors. However, the systems used to achieve this goal vary between agencies. In Queensland, the Herbarium has adopted a system based on a combination of Specht (1970) and Beadle and Costin (1952), whereas the DoE follows Walker and Hopkins’ (1990) system. More recently, DoE has favoured the concept of regional ecosystems. In South Australia, DHUD uses the concept of character species of Braun-Blanquet. This concept is also used by Victoria’s

DNRE in its system of floristic communities. DNRE has also developed ecological vegetation classes, an ecological process-orientated system, for the study of East Gippsland old-growth forests. Tasmania's NPWS and Forestry Tasmania use a floristic/structure/physiognomic system in some of their classification projects, e.g. the wet eucalypt forests.

4.3.2 Structural attributes

Most vegetation classification systems for conservation management use height and crown density in classifying vegetation types. However, the system of the Western Australian Department of Agriculture uses neither one and that of NPWS of Tasmania uses only height. Variation also exists in defining density amongst the systems that measure crown density. Some, such as New South Wales NPWS and Queensland DoE, use crown cover whereas others (Northern Territory PWCNT and South Australia DENR) use PFC. Hence the problem caused by using different methods of measuring density (crown cover and PFC), addressed in Section 4.2.3, also applies here. Other structural attributes such as stem density and basal area are inconsistently collected in different classification systems.

4.3.3 Vegetation status mapped

In most classifications for conservation management, vegetation classification and mapping projects aim to map present-day vegetation. The Queensland Herbarium maps vegetation as it was before European settlement (pre 1750) in the vegetation survey of Queensland. In that program, vegetation is mapped from existing vegetation and, in disturbed areas, from remnants and the analysis of landform, soil and climatic factors using field knowledge and API.

4.3.4 Climax concept

The definition of association outlined by Beadle and Costin (1952) is still being used by many agencies, notably PWCNT, BRI and SA DPI Forestry. It has been argued in ecological circles that the notion of vegetation 'climax' is not appropriate because vegetation rarely develops to a point at which both compositional and dynamic equilibria are reached. In any case, vegetation dynamics on a scale of less than one millennium has received little attention in Australia.

4.4 Strategic approaches in vegetation classification within individual agencies

There are three broad strategic approaches in the vegetation classification programs being undertaken by the major forest, conservation and environment management agencies:

- conducting a single classification across the whole State (e.g. SFNSW and PWCNT)
- conducting vegetation classification at regional level, but using the same methods in each region (e.g. Queensland Herbarium)
- using different methods depending on specific objectives of individual studies (e.g. NSW NPWS).

New South Wales NPWS has used the coastal vegetation mapping system, developed largely from Beadle, to classify the coastal vegetation in New South Wales; the multi-attribute vegetation mapping system for northern northeast New South Wales; the structural-physiognomic-floristic classification system for rainforests; and the Walker and Hopkins' system for wheatbelt. This kind of multi-method approach is the best way of meeting specific study objectives in particular areas. The disadvantage is, however, that it makes it difficult to compare the outcomes of these studies.

In a review of agricultural land evaluation in Australia, Shields *et al.* (1995) conclude that an objective and quantitative approach to land evaluation and survey is required. This also applies to vegetation classification and mapping, which must aim to provide a spatially-credible database to which wood production, conservation and management assessments can be applied.

4.5 Modelling techniques used for vegetation studies

A number of computer-based models have been used to predict the spatial distribution of individual plant or animal species, e.g. elapid snakes using BIOCLIM (Nix 1986), and *Eucalyptus* species using GLM (Austin *et al.* 1990). While a significant amount of work has been done on modelling the distribution of species, very little work has been attempted in Australia on the more complex issue of modelling the distribution of vegetation communities/assemblages. Ward (1995) used the decision tree CART and expert opinion to model a limited number of forest communities in southeast Queensland. Modelling of plant and species communities is still at the research stage in Australia, but there are plans to use such systems in the development of the national forest reserve system.

4.6 The need for a uniform approach in vegetation mapping

Uniformity in vegetation mapping methods is seen as a desirable goal by some ecologists and land managers in Australia, and a number of workshops have brought together vegetation ecologists to present current methods and issues. Some have resulted in published proceedings, notably Gillison and Anderson (1981) and Myers *et al.* (1984), while the outcomes of other workshops have not been published, e.g. the Australian Biological Resources Study sponsored national workshop at Brisbane in 1984. The Australian Soil and Land Survey Handbook, Field Handbook (McDonald *et al.* 1984, 1990) and Guidelines for Conducting Surveys (Gunn *et al.* 1988) were commissioned to recommend and promote the use of consistent procedures and terminologies in soil and land surveys. These publications have been widely accepted in the land resource community, but the vegetation classification system of Walker and Hopkins (1990) has not been as widely accepted by Australian vegetation ecologists/mappers.

Kirkpatrick and Dickinson (1986), after reviewing small scale vegetation mapping in Australia, concluded that uniformity of mapping unit characteristics, descriptive notation, scale and temporal integration is not necessarily possible or even desirable. This is particularly noticeable when the huge amount of variation in the environmental and ecological history of regions such as Tasmania, Western Australia and Queensland is considered. Hence, the 35 metre height threshold is an ecologically meaningful cutoff between predominantly wet sclerophyll and dry sclerophyll eucalypt forests in Tasmania (pers. comm. Mick Brown, Forestry Tasmania, Hobart). In northern Australia, by contrast, virtually no eucalypts reach such heights, and thresholds of 20 metres (Day and Forster 1975, Gillison and Walker 1981) and 25 metres (Neldner and Clarkson in press) have been found to separate distinct structural formations of *Eucalyptus tetrodonta* dominated woodlands.

5. Conclusions

Most vegetation classification systems reviewed are similar in using both floristics and structure as two primary elements in classifying vegetation types, and all use growth form (physiognomy) for distinguishing vegetation units.

However, these systems differ in the content and use of floristic and structural attributes. For floristics, all classifications for wood production purposes use only the dominant overstorey species with the emphasis on commercially important species, while most systems for conservation and environment management also use understorey species and species relationships. This reflects a difference in the classifications for different purposes. In CALM (Western Australia) for example, classifications overlap on the same area and different ones are used for different purposes (both in a conservation sense and a production sense). Of all vegetation classification systems reviewed, only two use the concept of character species derived from the Braun-Blanquet (BB) (1982) system, a method which produces similar outcomes to numerical classification methods. The low level of taxonomic knowledge, the poor mappability of many floristic communities, and a reluctance to adopt or devise acceptable alternatives to the latinised names for vegetation types of the BB system, have all inhibited its development in Australia.

While most vegetation classification systems use both height and crown density (e.g. crown cover or PFC) as the two major structural attributes, the systems of NPWS of New South Wales only use height and that of DLWC of New South Wales only uses crown density. Classifications are also different in assessing crown density; some use PFC whereas others use crown cover.

This review highlights the value of raw data of accurate quantitative measurements in the field, particularly for the two key structural attributes of height and crown density. It is important to gather measured data rather than classes or qualitative judgments. The raw measured data can be accommodated by a number of different classification schemes – in other words, it can be changed from one classification scheme to another. Taking such an approach can also provide a strong basis for developing a uniform classification system for Australian forest vegetation types.

6. References

- Aldrick, J. M. and Wilson, P. L. (1990) *Land systems of the southern Gulf Fall region, N.T.* Technical Report No. 42. Conservation Commission of the Northern Territory, Darwin.
- AUSLIG (1990) *Vegetation. Atlas of Australian resources.* Third series Volume 6. Australian Survey and Land Information Group, Canberra.
- Austin, M.P. (1978) Vegetation. In: *Land use of the south coast of New South Wales* Vol. 2 (ed. R.H. Gunn) Biophysical Background Studies. CSIRO, Melbourne.
- Austin, M.P. (1983) Problems of vegetation analysis for nature conservation. In: *Survey methods for natural conservation* (eds K. Myers, C.R. Margules and I. Musto) pp. 101-130. CSIRO, Canberra.
- Austin, M.P., Nicholls, A.O. and Margules, C.R. (1990) Measurement of the realised qualitative niche: environmental niches of five Eucalyptus species. *Ecological Monograph* 60: 161-177.
- Baur, G.N. (1962) *Forest vegetation in north-eastern New South Wales. Research Note no. 8.* Forestry Commission of NSW, Sydney.
- Baur, G.N. (1968) Developing a classification of forest types in N.S.W. Paper to 9th Commonwealth Forestry Conference.
- Beadle, N.C.W. (1981) *The vegetation of Australia.* Cambridge University of Press, London.
- Beadle, N.C.W. and Costin, A.B. (1952) Ecological classification and nomenclature. *Proceedings of Linnean Society of New South Wales* 77: 61-82.
- Beard, J.S. (1979a) Vegetation mapping in Western Australia. *Journal of the Royal Society of Western Australia* 62: 75-82.
- Beard, J.S. (1979b) *The vegetation of the Albany & Mt. Barker areas.* Vegmap Publications, Perth.
- Beard, J.S. (1980) A new phytogeographic map of western Australia. *WA Herbarium Res. Notes.* 3: 37-58.
- Beard, J.S. (1982) *Vegetation survey of Western Australia. Swan 1:1 000 000 vegetation series.* University of Western Australia, Perth.
- Beard, J.S. and Webb, M.J. (1974) *Vegetation survey of Western Australia - great sandy desert.* University of Western Australian Press, Perth.
- Beeston, G.R. (1978) Vegetation. In: *Western arid region land use study - Part 4*, Technical Bulletin No. 23. Department of Primary Industries, Brisbane.
- Belbin, L. (1988) *PATN reference manual.* CSIRO, Canberra.
- Belbin, L. (1991) The analysis of pattern in bio-survey data. In: *Natural conservation: cost-effective biological surveys and data analysis* (eds C.R. Margules and M.P. Austin) CSIRO, Canberra.
- Bentham, G. (1863-1878) *Flora Australiensis*, 7 volumes. Reeve, London. Reprinted (1967), Asher and Reeve, Amsterdam.
- Benson, D.H. (1986) The vegetation of the Gosford and lake Macquarie 1:100 000 vegetation map sheet. *Cunninghamia*. 1: 467-489.
- Benson, D.H. (1992) The natural vegetation of the Penrith 1:100 000 vegetation map sheet. *Cunninghamia*. 2: 541-596.
- Benson, D.H. and Howell, J. (1994) The natural vegetation of the Sydney 1:100 00 map sheet (with vegetation map of Ku-ring-gai National Park) (includes Ku-ring-gai 1:40 000 map) *Cunninghamia*. 3: 677-787.
- Benson, D.H. and Keith, D.A. (1990) The natural vegetation of the Wallerawang 1:100 000 map sheet. *Cunninghamia*. 2: 305-335.

- Benson, J.S. (1994) The native grasslands of the Monaro region: Southern Tablelands of New South Wales. *Cunninghamia* 3: 609-650.
- Benson, J.S. (1995) Sampling, strategies and costs of regional vegetation mapping. *Journal of Australian Map Circle* 43: 18-28.
- Benson, J. S. and Fallding, H. (1981) Vegetation survey of Brisbane Water National Park and environs. *Cunninghamia* 1: 79-114.
- Benson, J.S. and Jacobs, S.W.L. (1994) Plant communities of the Monaro lakes. *Cunninghamia*. 3: 651-676.
- Blake, S.T. (1938) The plant communities of western Queensland and their relationships, with special reference to the grazing industry. *Proceedings of the Royal Society of Queensland* 49:156-204.
- Bolton, M.P. (1992) *Vegetation from mapping to decision support. Report of a workshop to establish a set of core attributes for vegetation*. Environmental Resources Information Network, Canberra.
- Boomsma, C.D. and Lewis, N.B. (1981) *The native forest woodland and vegetation of South Australia*. Bulletin 25. South Australia Woods and Forests Department, Adelaide.
- Boyland, D.E. (1974) Vegetation. In: *Western arid region land use study - Part I*, Technical Bulletin No. 12. Department of Primary Industries, Brisbane.
- Boyland, D.E. (1980) Vegetation. In: *Western arid region land use study - Part II*, Technical Bulletin No. 22. Department of Primary Industries, Brisbane.
- Boyland, D.E. (1984) *Vegetation survey of Queensland. South Western Queensland*. Queensland botany bulletin no. 4. Queensland Department of Primary Industries, Brisbane.
- Braun-Blanquet, J. (1982) *Plant sociology: the study of plant communities*. McGraw Hill, New York.
- Brown, R. (1810) *Prodromus Florae Novae Hollandiae*. London.
- Brooker, M.G. and Margules, C.R. (in press) The relative conservation value of remnant patches of native vegetation in the wheatbelt of Western Australia. *Pacific Conservation Biology*.
- Buntine, D.G. (1974) *Orbost Shire forest land use report*. Forest Commission of Victoria, File No. 71/530 (unpubl.)
- CALM (Conservation and Land Management) (1992) *Management strategies for the south-west forests of Western Australia - a review*. Department of Conservation and Land Management, Perth.
- Carnahan, J.A. (1976) *Natural vegetation. Atlas of Australian resources*. Second Series (Dept. of Nat. Resources), Canberra.
- Carruthers, S. (1995) A summary of the Digital Vegetation Mapping available for the NPWS Reserves in South Australia. In: *Biological survey coordinating committee and geographic analysis and research unit vegetation mapping and analysis workshop notes*. Department of Housing and Urban Development, South Australia, Adelaide.
- Christian, C.S. and Perry, R.A. (1953) The systematic description of plant communities by the use of symbols. *Journal of Ecology* 41:100-105.
- Christian, C.S. and Stewart, G.A. (1953) *General report on survey of Katherine - Darwin Region*. Land Research Series, No. 1. CSIRO, Melbourne.
- Churchward, H.M. and McArthur, W.M. (1980) Landforms and soils of the Darling System, Western Australia. In: *Atlas of natural resources Darling system Western Australia explanatory text*. Department of Conservation and Environment, Perth.

- Clarkson, J.R. and Neldner, V.J. (in press) *Plants of Cape York Peninsula. An annotated checklist of the vascular flora*. Queensland Herbarium, Queensland Department of Environment and Heritage, Brisbane.
- Clements, F.E. (1904) *The development and structure of vegetation*. Botanical Survey of Nebraska.
- Clements, F.E. (1905) *Research methods in ecology*. Lincoln Press, Nebraska.
- Clements, F.E. (1907) *Plant physiology and ecology*. London.
- Clements, F.E. (1916) *Plant succession*. Publication No. 242. Carnegie Institute, Washington.
- Cochrane, G.R. (1963) A physiognomic vegetation map of Australia. *Journal of Ecology* 51: 639-655.
- Cochrane, G.R. (1967) The description and mapping of vegetation in Australia: A contribution to the International Biological Programme. *Victorian Naturalist* 84: 299-316.
- Copley, P.B. and Kemper, C.M. (eds) (1992) *A biological survey of the Yellabinna region of South Australia*. National Parks and Wildlife Service, South Australia Department of Environment and Land Management, Adelaide.
- Cowles, H.C. (1889) The ecological relations of the vegetation on the sand dunes of Lake Michigan. *Botanical Gazette* 27: 95-391.
- Cowles, H.C. (1901) The physiographic ecology of Chicago and vicinity. *Botanical Gazette* 31: 73-108.
- Crocker, R.L. (1959) Past climate fluctuations and their influence upon Australian vegetation. In: *Biogeography and ecology in Australia* (ed. A. Keast) Junk Publishers, Den Haag.
- Crocker, R.L. and Wood, J.G. (1947) Some historical influences on the development of South Australian vegetation communities and their bearing on concepts and classification in ecology. *Transactions of the Royal Society of South Australia* 71: 91-136.
- Dale, M.B., Hain, D., Lance, G., Milne, P., Ross, D., Thomas, M. and Williams, B. (1979) *TAXON users manual*. CSIRO, Canberra.
- Dansereau, P. (1951) Description and recording of vegetation on a structural basis. *Ecology* 32: 172-229.
- Davey, S.M., Dyne, G.R. and Bolton, M.P. (1993) *Standardising attributes to describe forest fauna habitat in Australia*. Bureau of Resource Sciences, Canberra.
- Day, K. J. and Czachorowshi, A. (1982) *Land Units of the Nabarlek mine area, N.T.* Technical Report No. 6. Conservation Commission of the Northern Territory, Darwin.
- Day, K.J. and Forster, B.A. (1975) *Report on the land units of Crocker Island, N.T.* 1972. Australian Government Publishing Service, Canberra.
- Day, K. J., Harrison, C. J. and Van Cuylenburg, H. R. M. (1979) *Land resources of Wildman River Station, N.T.* Technical Report No. 6. Conservation Commission of the Northern Territory, Darwin.
- DHUD (Department of Housing & Urban Development) (1995) *Guide to native vegetation survey; using the biological survey of South Australia methodology*. Department of Housing & Urban Development of South Australia, Adelaide.
- DNRE (Department of Conservation and Natural Resources) (1996) *Stand classes for 1:25 000 forest mapping*. Department of Conservation and Natural Resources, Melbourne (unpubl.)
- Dowling, R.M. and McDonald, W.J.F. (1976) *Moreton region vegetation map series: Brisbane*. Queensland Department of Primary Industries, Brisbane.
- Duncan, F. and Brown, M.J. (1985) *Dry sclerophyll vegetation in Tasmania: extent and conservation status of the communities*. Wildl. Divn. Tech. Rep. 85/1. National Parks and Wildlife Service of Tasmania, Hobart.

- Du Rietz, G.E. (1930) Classification and nomenclature of vegetation. *Svensk Botanisk Tidskrift* 24: 489-503.
- Du Rietz, G.E. (1931) Lifeforms of terrestrial flowering plants. *Acta Phytogeographica Suecica* 3: 1-95.
- Elsol, J.A. (1991) *Vegetation description and map. Ipswich, south-eastern Queensland*. Scale 1:250 000. Queensland Botany Bulletin No. 10, Queensland Department of Primary Industries, Brisbane.
- Elsol, J.A. and Dowling, R.M. (1978) *Moreton region vegetation map series: Beenleigh*. Queensland Department of Primary Industries, Brisbane.
- Elsol, J.A. and Sattler, P.S. (1979) *Moreton region vegetation map series: Caloundra*. Queensland Department of Primary Industries, Brisbane.
- FCNSW (Forestry Commission of NSW) (1989) *Forest types in New South Wales*. Research note 17. Forestry Commission of NSW, Sydney.
- Fisher, M., Ryan, K. and Lembit, R. (1995) The natural vegetation of the Burraborang 1:100 000 map sheet. *Cunninghamia* 4: 143-215.
- Floyd, A.G. (1990) *Australian rainforests in New South Wales*. Surrey Beatty & Sons, Chipping Norton, Sydney.
- Forbes, S.J., Gullan, P.K. and Walsh, N.G. (1981) *Sites of botanical significance in East Gippsland*. Study Series No. 322, Ministry for Conservation, Victoria, Melbourne.
- Forward, L. (1995), Biological Survey and Research Mapping. In: *Biological survey coordinating committee and geographic analysis and research unit vegetation mapping and analysis workshop notes*. Department of Housing and Urban Development of South Australia, Adelaide.
- Fosberg, F.R. and Pearsall, S.H. (1993) *Classification of non-marine ecosystems*. Atoll Research Bulletin No. 389. National Museum of Natural History, Washington.
- Fox, M.D. (1991) The natural vegetation of the Ana Branch-Mildura 1: 250 000 map sheet. *Cunninghamia* 2: 443-493.
- Gillison, A.N. (1981) Towards a functional vegetation classification. In: *Vegetation classification in Australia* (eds. A.N. Gillison and D.J. Anderson) pp. 30-41. CSIRO and Australian National University Press, Canberra.
- Gillison, A.N. (1984) Gradient sampling for resource surveys - the Gradsect method. In: *Survey methods for nature conservation* (eds. K. Myers, C.R. Margules and I. Musto) pp. 349-374. CSIRO Division of Water and Land Resources, Canberra.
- Gillison, A.N. (1988) *A plant functional proforma for dynamic vegetation studies and natural resource surveys*. CSIRO Institute of Natural Resources and Environment. Technical Memorandum 88/3.
- Gillison, A. N. and Anderson, D J. (1981) *Vegetation classification in Australia*. Australian National University Press, Canberra.
- Gillison, A.N. and Walker, J. (1981) Woodlands. In: *Australian vegetation* (ed. R.H. Groves) Cambridge University Press, Cambridge.
- Goodwins, D.R., Robinson, A.C., and Inns, R. (1989) *Classification and mapping systems used for forested land*. Department Environment and Planning of South Australia, Adelaide.
- Gould, P. (1995) Pastoral management branch landsystem mapping. In: *biological survey coordinating committee and geographic analysis and research unit vegetation mapping and analysis workshop notes*. Department of Housing and Urban Development of South Australia, Adelaide.
- Grisebach, A.R.H. (1872) *Die Vegetation der Erde*. Leipzig.
- Gullan, P.K. (1978) Vegetation of the Royal Botanic Gardens Annexe at Cranbourne, *Proceedings of the Royal Society of Victoria* 70: 225-40.

- Gullan, P.K., Walsh, N.G. and Forbes, S.J. (1981) Vegetation of the Gippsland Lakes catchment. *Muelleria* 4: 333-384.
- Gunn, R.H, Beattie, J.A, Reid, R.E. and van de Graaff, R.H.M. (1988) *Australian soil and land survey handbook: guidelines for conducting surveys*. Inkata Press, Melbourne.
- Harris, L.D. (1956) Regeneration of Jarrah (*Eucalyptus marginata*) *Australian Forestry* 20: 54-62.
- Hart, D. (1995) Use of Remote Sensing. In: *Biological survey coordinating committee and geographic analysis and research unit vegetation mapping and analysis workshop notes*. Department of Housing and Urban Development of South Australia, Adelaide.
- Havel, J.J. (1975a) *Site vegetation mapping in the northern Jarrah forest (Darling Range) 1. Definition of site vegetation types*. Forest Department of W.A. Bulletin 86, Perth.
- Havel, J.J. (1975b) *Site vegetation mapping in the northern Jarrah forest (Darling Range) 2. Location and mapping of site vegetation types*. Forest department of W.A. Bulletin 87, Perth.
- Heard, L.M.B. (1995) Vegetation mapping for regional surveys in the agricultural regions of South Australia. In: *Biological survey coordinating committee and geographic analysis and research unit vegetation mapping and analysis workshop notes*. Department of Housing and Urban Development of South Australia, Adelaide.
- Heddl, E.M., Loneragan, O.W. and Havel, J. (1980) *Vegetation complexes of the Darling system, Western Australia*. Department of Conservation and Land Management of Western Australia, Perth.
- Hill, M.O (1979) *TWINSPAN, a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes*. Cornell University, New York.
- Irvine, M (1994) *Evaluation of the suitability of growth stage mapping for old-growth studies of forest types in the D'Aguilar range, Queensland - for Queensland Department of Primary Industries Forest Service*. Department of Conservation and Natural Resources of Victoria, Melbourne.
- Jarman, S.J. and Brown, M.J. (1983) A definition of cool temperate rainforest in Tasmania. *Search* 14: 81-87.
- Jarman, S.J., Brown, M.J. and Kantvilas, G. (1984) *Rainforest in Tasmania*. National Parks and Wildlife Service of Tasmania, Hobart.
- Jarman, S.J., Brown, M.J. and Kantvilas, G. (1987) The classification, distribution and conservation status of Tasmanian rainforests. In: *The rainforest legacy, Australian national rainforests study*, Vol. 1, Special Australian Heritage Publication Series No. 7(1)
- Johnston, R.D. and Lacey, C.J. (1984) A proposal for the classification of tree-dominated vegetation in Australia. *Australian Journal of Botany* 32: 529-549.
- Keith, D. A. and Benson, D. H. (1988) The natural vegetation of the Katoomba 1:100 000 map sheet. *Cunninghamia* 2: 107-144.
- Keith, D.A. and Saunders, J.M. (1990) Vegetation of the Eden region, south-eastern Australia: species composition, diversity and structure. *Journal of Vegetation Science* 1: 203-232.
- Kestel Research (1990) *Review of vegetation classification and mapping systems*. Forestry Technical Services Pty Ltd, Canberra.
- Kinnear, S. (1995) Offpark Conservation Reserves. In: *Biological survey coordinating committee and geographic analysis and research unit vegetation mapping and analysis workshop notes*. Department of Housing and Urban Development of South Australia, Adelaide.
- Kirkpatrick, J.B. and Brown, M.J. (1991) Forest map of Tasmania 1:500 000 scale.

- Kirkpatrick, J.B. and Dickinson K. (1984) *Vegetation map of Tasmania 1:500,000*. Forestry Commission of Tasmania, Hobart.
- Kirkpatrick, J.B. and Dickinson, K.J.M. (1986) Achievements, concepts and conflict in Australian small-scale vegetation mapping. *Australian Geographic Studies* 24: 222-234.
- Kirkpatrick, J.B., Peacock, R.J., Cullen, P.J. and Neyland M.G. (1988) *The wet eucalypt forests of Tasmania*. Tasmanian Conservation Trust, Hobart.
- Küchler, A.W. (1947) A geographic system of vegetation. *The Geographical Review* 37: 233-240.
- Küchler, A.W. (1949) A physiognomic classification of vegetation. *Annals of the Association American Geographers* 39: 201-210.
- Küchler, A.W. (1956) Classification and purpose in vegetation maps. *The Geographical Review* 56: 155-167.
- Küchler, A.W. (1967) *Vegetation Mapping*. The Ronald Press company, New York.
- LCC (Land Conservation Council) (1974) *East Gippsland study area report*. Land Conservation Council, Melbourne.
- LCC (1977) *Alpine study area report*. Land Conservation Council, Melbourne. pp. 480.
- LCC (1982) *Gippsland Lakes hinterland study area report*. Land Conservation Council, Melbourne.
- LCC (1991) *Melbourne area (2) review and descriptive report*. Land Conservation Council, Melbourne.
- Lock, E. and Goodwins, D.R. (1994) *A vegetation survey of the Western Murray flats - preliminary classification mapping*. Department of Housing and Urban Development, of South Australia, Adelaide.
- McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (eds) (1984) *Australian soil and land survey field handbook*. First Edition. Inkata Press, Melbourne.
- McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (eds) (1990) *Australian soil and land survey field handbook*. Second Edition. Inkata Press, Melbourne.
- McDonald, W.J.F. and Whiteman, W.G. (1979) *Moreton Region Vegetation Map Series: Murwillumbah*. Queensland Department of Primary Industries, Brisbane.
- McNamara, P.J. (1959) *Air photo mapping of the West Australian eucalypt forests*. Papers and Proceedings ANZAAS, Perth.
- McRae, R. H. D. and Cooper, M. G. (1985) Vegetation the Merriwa area, New South Wales. (including 1:100 000 vegetation map) *Cunninghamia* 1: 351-370.
- Moore, R.M. and Perry, R.A. (1970) Vegetation. In: *Australian Grasslands* (ed. Moore, R.M.) Australian National University Press, Canberra.
- Mueller, F.J.H. von (1858-1882) *Fragmenta phytographiae Australiae*, Volumes 1-7, Government Printer, Melbourne.
- Muir, B.G. (1977) *Biological survey of the Western Australian Wheatbelt. Part 2: Vegetation and Habitat of the Bendering Reserve*. Western Australian Museum, Perth.
- Myers, K., Margules, C.R. and Musto, I. (eds) (1984) *Survey methods for natural conservation*. Volumes 1 and 2. CSIRO, Canberra.
- Neldner, V.J. (1984) *Vegetation survey of Queensland. South central Queensland*. Queensland Botany Bulletin no. 3. Queensland Department of Primary Industries, Brisbane.
- Neldner, V.J. (1991) *Vegetation survey of Queensland. Central Western Queensland*. Queensland Botany Bulletin no. 9. Queensland Department of Primary Industries, Brisbane.

- Neldner, V.J. (1993) *Vegetation survey and mapping in Queensland*. Queensland Botany Bulletin No. 12. Queensland Department of Environment and Heritage, Brisbane.
- Neldner V.J. and Clarkson J.R. (1995) *Vegetation survey and mapping of Cape York Peninsula*. Cape York Peninsula Land Use Strategy, Office of the Co-ordinator General and Queensland Department of Environment of Heritage, Brisbane.
- Neldner V.J. and Clarkson J.R. (in press) *Vegetation of Cape York Peninsula*. Queensland Herbarium, Queensland Department of Environment of Heritage, Brisbane.
- Neyland, M. (1986) *Conservation and management of tree ferns in Tasmania*. Wildlife Div. Tech. Rep. no. 86/1. National Parks and Wildlife Service of Tasmania, Hobart.
- Nix, H.A. (1986) A biogeographic analysis of Australian Elapid snakes. In: *Atlas of elapid snakes of Australia, Australian flora and fauna series number 7* (ed. R. Longmore) pp. 4-15. Australian Government Publishing Service, Canberra.
- NPWS (National Parks and Wildlife Service) (1995) *Vegetation survey and mapping of upper north east New South Wales*. New South Wales National Parks and Wildlife Service, Sydney.
- Owens, H.M., Robinson, A.C., Dendy, A.T.H., and Lang, P.J. (1995a) *A biological survey of Messent Conservation Park, South Australia*. Department of Environment and Natural Resources of South Australia, Adelaide.
- Owens, H.M., Hudspith, T.J., Robinson, A.C., Dobrinski, I., Armstrong, D.M. Pedlar, L.M. and Land, P.J. (1995b) *A biological survey of Yumbarra Conservation Park, South Australia*. Department of Environment and Natural Resources of South Australia. Adelaide.
- Pannell, J.R. (1992) *Swamp Forests of Tasmania*. Forestry Commission, Tasmania.
- Parkes, D., Moorrees, A. and Williams, J. (1984) *A floristic vegetation map of east Gippsland (1:250 000)* Department of Conservation, Forests & Lands of Victoria, Melbourne.
- Patton, R.T. (1933) Ecological studies in Victoria. Part II. The Fern Tree Gully *Proceedings of the Royal Society of Victoria* 46: 117-129.
- Patton, R.T. (1934) Ecological studies in Victoria. Part III. Coastal sand dunes. *Proceedings of the Royal Society of Victoria* 47: 135-157.
- Patton, R.T. (1936) Ecological studies in Victoria. Part IV. Basalt plains association. *Proceedings of the Royal Society of Victoria* 48: 172-190.
- Pedley, L. (1967) Vegetation of the Nogoia-Belyando area. *CSIRO Land Research Series No. 18*. pp. 138-169. CSIRO, Canberra.
- Pedley, L. (1974) Vegetation of the Balonne-Maranoa area. *CSIRO Land Research Series No. 34*. pp. 180-203. CSIRO, Canberra.
- Pedley, L. (1988) Vegetation survey. In: *Australian soil and land survey handbook: guidelines for conducting surveys* (eds. R.H. Gunn, J.A. Beattie, R.E. Reid and R.H.M. van de Graaff) pp. 135-142. Inkata Press, Melbourne.
- Pedley, L. and Isbell, R.F. (1971) Plant communities of Cape York Peninsula. *Proceedings of the Royal Society of Queensland* 82: 51-74.
- Pickhard, J. and Boyland, D. E. (1981) Comparison of three small-scale (1:1 million) vegetation mapping techniques. In: *Vegetation Classification in Australia* (eds. A.N. Gillison and D J. Anderson) pp. 86-96. Australian National University Press, Canberra.
- Playfair, R.M. and Heard, L.M.B. (1994) *A vegetation survey of the Western Murray flats of South Australia*. South Australia Department of Housing and Urban Development, Adelaide.
- Playfair, R.M. and Heard, L.M.B. (1995) *A native vegetation survey of the Burra Hills region of South Australia*. South Australia Department of Housing and Urban Development, Adelaide.

- Porteners, M. F. (1993) The natural vegetation of the Hay Plain: Booligal-Hay and Deniliquin-Bendigo 1:250 000 maps. *Cunninghamia* 3: 1-122.
- Prescott, J.A. (1931) *The soils of Australia in relation to vegetation and climate*. Bulletin No. 52. Council of Scientific and Industrial Research, Australia. Canberra.
- Preston, R (1989) *Interim forest type classification system*. A paper presented at NFI Vegetation Classification Workshop held at Canberra in 1989. National Forest Inventory, Canberra.
- Pringle, H.J.R., Van Vreeswyk, A.M.E. and Gilligan, S.A. (1994) *An inventory and condition survey of the north-eastern Goldfields, Western Australia*. Technical Bulletin No. 87. Department of Agriculture of Western Australia, Perth.
- Purdie, R.W. (1990) Vegetation. In: *Western arid region land use study - Part VI*, Technical Bulletin No. 28. Department of Primary Industries, Brisbane.
- Purdie, R.W. and McDonald, W.J.F. (1990) Vegetation. In: *Western arid region land use study - Part III*, Technical Bulletin No. 29. Department of Primary Industries, Brisbane.
- QDF (Queensland Department of Forestry) (1986) *Your forests*. Department of Forestry, Brisbane.
- RAC (Resource Assessment Commission) (1992) *Forest and timber inquiry - Final report*. Resource Assessment Commission. Australian Government Publishing Service, Canberra.
- Richards, P.W., Tansley, A.G. and Watt, A.S. (1940) The recording of structure, lifeform and flora of tropical forest communities as a basis for their classification. *Journal of Ecology* 28: 224-239.
- Ritman, K.T. (1995) *Structural vegetation data: a specifications manual for the Murray Darling Basin Project M305*. NSW Department of Land and Water Conservation, Sydney.
- Russell-Smith, J. (1991) Classification, species richness and environmental relations of monsoon rain forest in northern Australia. *Journal of Vegetation Science* 2: 259-278.
- Scott, J. A. (1992) The natural vegetation of the Balranald-Swan Hill 1:250 000 area. *Cunninghamia* 2: 597-652.
- Schimper, A.F.W. (1903) *Plant geography upon a physiological basis*. Oxford University and Clarendon Press, London.
- Shields, P. G., Smith, C. D. and McDonald, W. S. (1995) *Agricultural land evaluation in Australia. A review*. Australian Collaborative Land Evaluation Program, Canberra.
- Sivertsen, D. and Day, K. J. (1985) *Land resources of the Katherine Gorge National Park*. Technical Report No. 20. Conservation Commission of the Northern Territory, Darwin.
- Sivertsen, D. and Metcalfe, L. (1995) Natural vegetation of the southern wheat-belt (Forbes and Cargelligo 1:250 000 map sheets) *Cunninghamia* 4: 103-128.
- Smith, F. G. (1972) *Vegetation survey of Western Australia: Vegetation map: Pemberton (and) Irwin Inlet*. Western Australia Department of Agriculture, Perth.
- Smith, F. G. (1973) *Vegetation survey of Western Australia: Vegetation maps of Busselton and Augusta*. Western Australia Department of Agriculture, Perth.
- Smith, F. G. (1974) *Vegetation survey of Western Australia: Vegetation map of Collie Sheet, 1:250 000*. Western Australia Department of Agriculture, Perth.
- Society for Range Management (1991) SRM recommends new range terminology. Trailboss News, Supplement to Journal of Range Management. September 1991.
- Specht, R.L. (1957) Dark Island heath (Ninety-Mile Plains, South Australia) V. The water relationships in heath vegetation and pastures on the Makin sand. *Australian Journal of Botany* 5: 151-172.
- Specht, R.L. (1963) Dark Island heath (Ninety-Mile Plain, South Australia) VII. The effect of fertilisers on composition and growth, 1950-1960. *Australian Journal of Botany* 11: 67-94.
- Specht, R.L. (1970) Vegetation. In: *Australian environment* (ed. G.W. Leeper) 4th edn. Melbourne University Press, Melbourne. pp. 44-67.

- Specht, R.L. (1981) Projective foliage cover and standing biomass. In: *Vegetation classification in Australia* (eds. A.N. Gillison and D.J. Anderson) pp. 10-21. CSIRO, Canberra.
- Specht, R.L., Roe, E.M. and Boughton, V.H. (1974) Conservation of major plant communities in Australia and Papua New Guinea. *Australian Journal of Botany* Suppl. 7. CSIRO, Melbourne.
- Strelein, G.J. (1988) *Site classification in the southern Jarrah forest of Western Australia*. Department of Conservation and Land management. Research Bulletin 2, Perth.
- Thompson, J., Bean, T. and Dillewaard, H. (1996) *Methodology for vegetation survey and mapping for eastern Queensland*. Queensland Herbarium, Brisbane.
- Turner, E.J., McDonald, W.J.F., Ahern, C.R. and Thomas, M.B. (1993) *Western arid region land use study - Part V*. Queensland Department of Primary Industries Technical Bulletin No. 30, Brisbane.
- Walker, J. and Hopkins, M.S. (1990) Vegetation. In: *Australian soil and land survey: Field handbook* (McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S.) p. 58-86. Inkata Press, Melbourne.
- Ward, D.P. (1995) *Modelled tree species distribution and forest types for the Caboolture, Esk, Helidon and Ipswich regions of south-east Queensland*. Queensland Department of Primary Industries Forest Service, Brisbane.
- Warming, E. (1909) *Oecology of plants*. Clarendon Press, Oxford.
- Webb, L.J. (1959) A physiognomic classification of Australian rain forests. *Journal of Ecology* 47: 551-570.
- Webb, L.J. (1968) Environmental relationships of the structural types of Australian rainforest vegetation. *Ecology* 49: 296-311.
- Webb, L.J. (1978) A general classification of Australian rainforests. *Australian Plants* 9: 349-363.
- Wells, G., Coorey, R., Gordon, I. and Ingwersen, F. (1989) *Classification and mapping systems for forested land*. A paper presented at NFI Vegetation Classification Workshop held at Canberra in 1989. National Forest Inventory, Canberra.
- Whittaker, R.H. (1962) Classification of natural communities. *Botanical Review* 28: 1-239.
- Williams, R.J. (1955) Vegetation regions. In: *Atlas of Australian resources*. Department of National Development, Canberra.
- Wilson, B.A., Brocklehurst, P.S., Clark, M.J. and Dickinson, K.J.M. (1990) *Vegetation survey of the Northern Territory*. Technical Report No. 49. Conservation Commission of the Northern Territory, Palmerston, NT.
- Wood, J.G. (1936) Regeneration of the vegetation on the Koonamore Vegetation Reserve, 1926-1936. *Transactions of the Royal Society of South Australia* 60: 96-111.
- Wood, J.G. (1937) *The vegetation of South Australia*. Government Printer, Adelaide.
- Wood, J.G. (1939) Ecological concepts and nomenclature. *Transactions of the Royal Society of South Australia* 63: 215-223.
- Wood, J.G. (1949) Vegetation of Australia. In: *The Australian environment*. First Edition. pp. 77-96. CSIRO, Melbourne.
- Wood, J.G. and Williams, R.J. (1960) Vegetation of Australia. In: *The Australian environment* (revised edition) (ed. G.W. Leeper) pp. 67-84. CSIRO and Melbourne University Press, Melbourne.
- Woodgate, P.W., Peel, W.D., Ritman, K.T., Coram, J.E., Brady, A., Rule, A.J. and Banks, J.C.G. (1994) *A study of the old-growth forests of East Gippsland*. Department of Conservation and Natural Resources of Victoria, Melbourne.
- Young, P.A.R. (1995) *Conservation status of Queensland's bioregional ecosystems: draft summary*. Queensland Department of Environment and Heritage, Brisbane.

Young, P.A.R. and McDonald, T.J. (1989) *Vegetation map and description. Warwick, south-eastern Queensland. Scale 1:250 000.* Botany Bulletin No. 8, Queensland Department of Primary Industries, Brisbane.

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Abbreviations

ACTFS	Australian Capital Territory Forest Service
API	aerial photo interpretation
BB	Braun-Blanquet
BRI	Queensland Herbarium
BRS	Bureau of Resource Sciences
BVG	broad vegetation group
CALM	Western Australian Conservation and Land Management
DENR	South Australian Department of Environment and Natural Resources
DHUD	South Australian Department of Housing and Urban Development
DLWC	New South Wales Department of Land and Water Conservation
DNRE	Victorian Department of Natural Resources and Environment
DoE	Queensland Department of Environment
DPI	South Australian Department of Primary Industries
EVC	ecological vegetation classes
FCNSW	Forestry Commission Of New South Wales
FCV	Forests Commission of Victoria
GIS	geographic information system
LCC	Victorian Land Conservation Council
m	million
NPWS	National Parks and Wildlife Service
NSW	New South Wales
PFC	projective foliage cover
PWCNT	Parks and Wildlife Commission of the Northern Territory
QDPI	Queensland Department of Primary Industries
RBGS	Royal Botanic Gardens Sydney
SFNSW	State Forests of New South Wales
WARLUS	Western Arid Region Land Use Study



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